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1961
ANNUAL PROGRESS REPORT
RANGE REVEGETATION INVESTIGATIONS

FORAGE & RANGE BRANCH
CROPS RESEARCH DIVISION
AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

UTAH AGRICULTURAL EXPERIMENT STATION
and
INTERMOUNTAIN FOREST
AND RANGE EXPERIMENT STATION

by

A.T. BLEAK, RANGE CONSERVATIONIST
LOGAN, UTAH

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UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
Crops Research Laboratory
Utah State University
Logan, Utah
April 10, 1962

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RESEARCH
INTERMOUNTAIN

Dr. Weldon O. Shepard
Intermountain Forest and Range
Experiment Station
Forest Service Building
Ogden, Utah

Dear Shep:

Enclosed is a copy of my 1961 Annual Progress Report. This report covers most of the work conducted from April 1, 1961 to March 31, 1962.

I wish to express my appreciation for the kind cooperation by you and your staff while I was located at Ephraim and also since my transfer to Logan. I enjoyed working at Ephraim and the association with A.P. Plummer and staff. I still have considerable work in the Ephraim area and plan to follow this work for several years.

Sincerely yours

A.T. Bleak
Range Conservationist

ATB:JJ

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ACKNOWLEDGEMENT

Work covered in this report is cooperative among the following agencies:

Bureau of Land Management

Forest Service, Region 4

Intermountain Forest and Range Experiment Station

Soil Conservation Service

Utah State University

Appreciation is expressed to all personnel who assisted in laboratory or field work, reviewed study plans or manuscripts, and for their many helpful suggestions. Special thanks are due the Utah State University and the Intermountain Forest and Range Experiment Station and Forest Service, Region 4, for providing office and storage space and other services.

NOT FOR PUBLICATION- This is a progress report of cooperative investigations containing data, the interpretation of which may be modified with additional experimentation. Publication, display or distribution of any data or any statements herein is prohibited without prior written approval of the Crops Research Division, ARS, USDA, and the cooperation agency or agencies concerned.

Copies of this report were submitted to the following:

Two copies (1 and 2):
Forage & Range Branch
Crops Research Division
Plant Industry Station
Beltsville, Maryland

One copy (3):
Director
Utah Agricultural Experiment Station
Utah State University
Logan, Utah

One copy (4):
Director
Intermountain Forest & Range Experiment Station
Forest Service, USDA
Ogden, Utah

One copy (5):
Project files
Logan, Utah

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CR c6: PASTURE AND RANGE INVESTIGATIONS UNDER ARID, SEMIARID, AND SUBHUMID CONDITIONS

I. Introduction

The following report covers the artificial revegetation investigation conducted in central and northern Utah during 1961. Headquarters for this project was moved from Ephraim to the Utah State University at Logan, Utah in June 1961. Short term studies and studies requiring frequent observations were terminated. Major emphasis has been placed on analysis of data and preparation of reports. Active studies in central Utah will be followed to a logical conclusion.

Research has been primarily in three fields:

1. Development of improved forage production on arid grazing lands -- Suitable species are needed to increase forage production, to maintain soil stability, and prevent destructive floods. Species should be used which are adapted to the environment. Species may be well adapted to a particular climate or soil, but still fail because of other environmental factors. This has led to an effort to distinguish between those inherent climatic and edaphic factors which must be met by species selection as opposed to factors such as grazing use, insects, rodents, and disease.

2. Methods of seeding and establishing forage plants on arid grazing lands -- Suitable establishment practices are necessary for consistently successful and effective revegetation of depleted ranges on which the present plant cover is not adequate for soil protection or is of low forage value. The reseeding program is expanding into extremes of climate and soils where little is known about reseeding. This magnifies the importance of "know-how" in restoring the vegetation

cover. Low precipitation, dry summer, sandy soil, acid soil, steep slopes and rough terrain are some of the factors which require special consideration.

3. Physiology of range and pasture plants -- Physiological studies on response of plants to environment factors provide information needed for selection of suitable species and methods and for successful establishment and managagement. Reasons for specific responses by seeds and plants to certain factors in the environment must be understood to predict behavior from site to site. This understanding will not only assist in selection of species, sites, and management, but should also show where modification of certain environment factors may be desirable.

A. Foreign visitors and Technical Assistance

Approximately 6 hours were spent with Mariano Segura from Peru and Buhar Kolo from Nigeria. In addition, 32 hours were spent giving technical assistance and reviewing research findings with extension workers, action agencies and private groups.

B. Vehicles at Logan and Ephraim, Utah

1. 1954 truck pickup, 1/2 ton, Ford, V-1655-ARS, licence A-52355. Mileage on March 1, 1962 was 62,489. Good condition.

2. 1955 truck pickup, 1/2 ton, Willys Jeep, V-2593-ARS, licence A-57211. Mileage on March 1, 1962 was 39,721. Vehicle is in very poor condition and not safe to drive.

II. Legume-grass mixtures on rangelands

The advantages of grass-legume mixtures for conservation work and for pasture mixtures on farmland in sub-humid areas and under irrigation have long been recognized. However, little work has been done on grass-legume mixtures for western rangelands. Many of the legumes suited for irrigated land will not grow on the more arid rangelands. Many of these legumes have a single taproot which is easily destroyed by gophers or other digging animals, killing the plant.

This study is located on a small plot in the mountain brush type in Ephraim Canyon. Elevation is about 7,200 feet and annual precipitation is about 18 inches. The soil is a silt loam from limestone origin. The study site was cleared prior to planting. During the spring of 1950 the study area was burned. Stumps and remaining shrubs were cleared by disking and hand grubbing.

Prior to burning the vegetative cover was primarily big sagebrush interspersed with small patches of oak and snowberry. A few remnants of Agropyron spicatum, Sitanion hystrix, Oryzopsis hymenoides, and Lupinus could be found under the shrubby species. Bromus tectorum and other annuals were abundant in the openings.

This study was established to determine the best legumes for planting in grass-legume mixtures and determining the effects of the grass-legume mixture on yield of the grasses and legumes in range planting on mountain brush ranges.

Nine legumes including three separate strains of alfalfa were planted in mixture with each of four promising grass species in the fall of 1950. Species and strains used are listed on the next page.

GRASSES

Agropyron desertorum - Lot Ager 78, Commercial. Grown in Sanpete Valley, Utah in 1950.
Agropyron intermedium - Lot 42, Pullman, Washington SCS No. P-2327. Grown in 1945.
Bromus carinatus - Lot 32, progeny of native seed from near Enterprise, Utah. Grown in 1949.
Bromus inermis - Lot 47, Lincoln, progeny of certified seed. Grown in 1950.

LEGUMES

Astragalus cicer - Lot 9, Pullman, Washington SCS No. P-498. Grown in 1946.
Astragalus falcatus - Lot 11. Grown at SCS Nurseries in Bellingham Nursery. Received in 1948.
Lathyrus sylvestris - Lot 5, Pullman, Washington SCS No. P-27. Received in 1949.
Lotus corniculatus - Lot 5, Pullman, Washington SCS No. P-735. Received in 1949.
Medicago falcata - Lot 1A. Grown in 1947. Progeny of seed obtained from University of Alaska.
Medicago sativa - Lot Megl B. Progeny of A169, grown in 1950.
Medicago sativa - Lot 7, Ladak, Kelley Western Seed Company, certified. Grown in Idaho in 1945.
Medicago sativa - Lot 14, Rhizome, Northrup, King and Company, Lot N431. Grown in New Mexico in 1949.
Vicia tenufolia - Lot 6, Pullman, Washington SCS No. P-692. Grown in 1948.

An area 80 x 90 feet was divided into 4 equal blocks and each block was divided into 4 sub-blocks. Each sub-block contains 9 plots which are 5 feet wide and 10 feet long. Three furrows 20 inches apart were made the length of the plots. Seed of 1 grass species was placed in all furrows at a rate of 8 to 10 pounds per acre. Seed of each of the 9 legume species was planted at a rate of 8 to 10 pounds per acre. Assignment of grass species to sub-blocks was at random and placement of legume species within a sub-block is at random. Seed was then covered with soil to a depth of 3/4-inch and the soil was firmed.

During the period 1950 to 1953 the area was poisoned and trapped to keep pocket gophers and digging animals out of the study area. Plant numbers and yield were taken in 1951, 1952, and 1953. During the next 3 years this area was poisoned at intervals but in general natural condition in respect to grazing use by animal life prevailed. In the early spring of 1957 all old herbage from previous years was removed from the area, pocket gophers were poisoned and trapped, and a rabbit and deer exclosure was constructed around the study. In 1957, 1958, and 1959, the number of legume plants in each plot was counted. The legume plants were hand clipped on each plot and the grass was then mowed with a scythette. The legume and grass herbage was individually sacked and green weights were taken. Air dry weights were taken on all samples. Oven dry weights were taken on selected samples. Plant counts and supplemental information were also taken on longevity of grass-legume mixtures in 1961. The 1958, 1959, and 1961 data did not change the conclusions.

Analysis of data is nearly complete and a paper for the Journal of Range Management is being prepared. Of the four grass species used, mountain brome was most compatable with the legume species used. However, this short-lived grass had largely died out by 1957. Herbage production of legumes was smallest when grown with intermediate wheatgrass. Legumes growing with crested wheatgrass and smooth brome produced similar yield. The strains of alfalfa were superior in both number and herbage production to other species, but Astragalus cicer also made a good showing. Astragalus falcatus and Medicago falcata ? produced fair stands. Lathyrus sylvestris, Lotus corniculatus and Vicia tenufolia failed to produce fair stands in mixtures with these grasses on the mountain brush site.

III-A. Depth of planting and seedling emergence.

Depth of planting studies have been conducted in crop years 1959, 1960, and 1961. Emergence studies have been conducted in crop years in 1960 and 1961. Data for 1959 and 1960 were included in the reports for those years.

Seeds of eight species were planted at three locations in Ephraim Canyon in the fall of 1960. Sites were located at elevations of 5,500 feet (Sorenson's Field), 7,000 feet (Majors Flat), and 8,850 feet (Headquarters Station). This study was established to provide information on ability of seeds to germinate, depth of emergence, seedling establishment, and seed dormancy at various depths below the soil surface.

Species used in this study were: (1) Agropyron desertorum, 1960 seed grown at Majors Flat; (2) A. intermedium, 1960 seed grown in Sanpete county; (3) A. trachycaulum, 1960 seed collected at 10,000 feet in Ephraim Canyon; (4) Avena fatua, 1960 seed collected in Sanpete county; (5) Bromus carinatus, 1960 seed collected at 10,000 feet in Ephraim Canyon; (6) B. inermis, 1960 seed, Headquarters Nursery; (7) Rambler alfalfa, commercial; and (8) Winter club barley, commercial.

Seed lots were screened to remove impurities and all light seeds and then treated with Orthocide 75. Seeds used in the depth of planting study were placed in nylon bags with 100 seeds of a single species per bag except 50 seeds per bag for wild oats. Seeds used in the emergence study were separated into units of 50 seeds for all species.

Seeds in bags were placed at the following depths: 1/2, 1, 2, 4, 6, 12, and 24 inches. Two replications were placed at each depth.

Plantings were made on October 19 at the upper site and on October 26 at the middle and lower sites. Seeds in bags were removed the following spring just as the soil was drying(figure 1).

Seeds from the 1/2-inch, 1-inch, and 2-inch depths were removed from the 5,500 feet site on May 8, May 9, and May 11, respectively. The 4-, 6-, 12-, and 24-inch depths were removed on May 16. Table 1 shows that germination was high for most species at all depths. Some additional germination occurred in the germinator but this was very low for all species except at the 1/2- and 1-inch depths for alfalfa at the 5,500 feet site and the 6-, 12-, and 24-inch depths for smooth brome at all sites. Variation in depth of planting was relatively small due to high germination of most species at all depths.

Maximum shoot penetration, found when the nylon bags were removed, was 9.5 inches for the shoots of wild oats from the 2-foot depth at the 7,000 feet site. Maximum penetration for intermediate wheatgrass and slender wheatgrass was about 90 mm. Maximum penetration of the soil by barley was 120 mm.

In the emergence study, seed of the 8 species were planted in rows 25 inches long and 6 inches apart at depths of 1/2, 1, 2, 4, and 6 inches. Fifty seeds of a single species were uniformly placed along each row. Each species was replicated four times at each depth. Plantings at the 1/2 and 1 inch depths were made by making individual rows. The 2-, 4-, and 6-inch depths were planted in the bottom of trenches that were the desired depth and the original soil was replaced in the trench.

At each location seedling counts were first made in the early

Figure 1 . Seeds in nylon bags were planted at depths of 1/2, 1, 2, 4, 6, 12, and 24 inches at this site (5,500 ft.) and also at 7,000 and 8,500 feet elevations in Ephraim Canyon which can be seen in the background (61-32).

Table 1 . Percent of seeds germinated when removed from soil and after 35 additional days in a germinator (complete), that had been planted at three elevations in late October 1960 at seven depths and removed just as the soil was drying in the spring of 1961.

Depth		Crested wheatgrass			Intermediate wheatgrass			Slender wheatgrass			Alfalfa		
		5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/
		Percent											
1/2 inch	Removed	89.7	95.0	80.0	98.0	98.0	93.0	61.5	93.0	92.0	55.0	86.5	93.5
	Complete	89.7	95.0	82.5	98.0	98.0	93.5	63.0	93.5	99.0	90.0	87.5	94.5
1 inch	Removed	85.3	86.5	82.0	99.0	98.0	94.5	88.5	99.5	92.0	51.5	89.5	95.5
	Complete	85.3	92.0	82.5	99.0	98.0	94.5	90.0	99.5	96.5	82.5	89.5	95.5
2 inches	Removed	95.7	92.5	89.0	98.7	96.5	94.5	99.0	98.5	98.0	80.5	90.5	95.0
	Complete	95.7	92.5	90.5	98.7	96.5	94.5	99.0	98.5	98.0	83.5	91.0	95.0
4 inches	Removed	96.3	94.5	92.5	98.3	98.0	94.0	98.0	99.0	98.5	90.5	89.0	95.5
	Complete	96.3	95.0	93.0	98.3	98.0	94.0	98.0	99.5	98.5	91.0	89.0	95.5
6 inches	Removed	98.3	96.5	89.5	98.3	97.5	96.0	92.5	99.0	99.0	76.0	86.5	91.0
	Complete	98.7	96.5	90.5	98.3	98.0	96.0	94.0	99.5	99.0	90.0	87.0	91.0
1 foot	Removed	98.3	97.5	86.0	97.3	98.5	95.0	94.0	98.0	97.0	92.0	90.0	96.0
	Complete	98.3	97.5	86.0	97.7	99.0	95.0	95.0	98.0	97.0	92.5	90.0	96.0
2 feet	Removed	98.3	95.5	95.5	97.7	98.0	97.0	60.0	73.5	97.5	89.0	87.0	91.5
	Complete	98.7	95.5	95.5	98.3	98.0	97.5	72.0	96.0	97.5	90.5	87.0	91.5

1/ Seed removed on May 3, at 1/2 inch; May 9, at 1 inch; May 11 at 2 inches; and May 16 at 4 and 6 inches, 1 foot, and 2 feet.

2/ Seed removed on May 25, at 1/2 and 1 inch depths. Depths of 2, 4, and 6 inches, 1 foot and 2 feet were removed on June 1.

3/ Seed removed on June 12, at 1/2, 1, 2, 4, and 6 inch depths. Depths of 1 foot and 2 feet were removed on July 6.

Table 1 .--(continued)

Depth		Barley			Mountain brome			Smooth brome			Wild oats		
		5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/
		Percent											
1/2 inch	Removed	97.5	95.5	89.0	89.0	97.5	86.5	83.7	90.0	69.0	91.0	54.0	6.0
	Complete	97.5	95.5	89.0	89.0	97.5	87.0	85.0	90.0	89.5	93.0	56.0	7.0
1 inch	Removed	93.0	96.0	93.0	97.5	91.0	90.0	79.7	87.5	81.5	92.0	64.0	20.0
	Complete	93.5	96.0	93.0	97.5	91.0	90.0	79.7	87.5	83.5	93.0	66.0	21.0
2 inches	Removed	96.0	97.0	97.5	99.0	98.0	96.5	84.8	86.5	86.5	94.0	78.0	93.0
	Complete	96.0	97.0	97.5	99.0	98.0	96.5	85.3	86.5	86.5	97.0	78.0	93.0
4 inches	Removed	97.5	97.0	99.5	98.5	99.0	96.0	82.7	85.0	75.5	96.0	89.0	96.0
	Complete	97.5	97.0	99.5	98.5	99.0	96.0	92.0	87.5	75.5	96.0	89.0	96.0
6 inches	Removed	98.5	97.0	98.0	99.5	99.0	97.0	64.0	78.0	82.5	98.0	95.0	85.0
	Complete	98.5	97.0	98.0	99.5	99.0	97.0	91.7	95.0	83.5	98.0	97.0	85.0
1 foot	Removed	99.5	96.5	97.0	99.0	98.5	99.0	69.0	68.0	88.5	97.0	95.0	98.0
	Complete	99.5	96.5	97.0	99.0	98.5	99.0	94.3	95.0	92.5	97.0	96.0	98.0
2 feet	Removed	98.0	99.0	99.5	99.0	100.0	92.5	64.3	67.5	74.0	95.0	99.0	97.0
	Complete	98.0	99.0	99.5	99.0	100.0	92.5	95.3	94.0	89.5	95.0	99.0	97.0

1/ Seed removed on May 3, at 1/2 inch; May 9, at 1 inch; May 11 at 2 inches; and May 16 at 4 and 6 inches, 1 foot, and 2 feet.

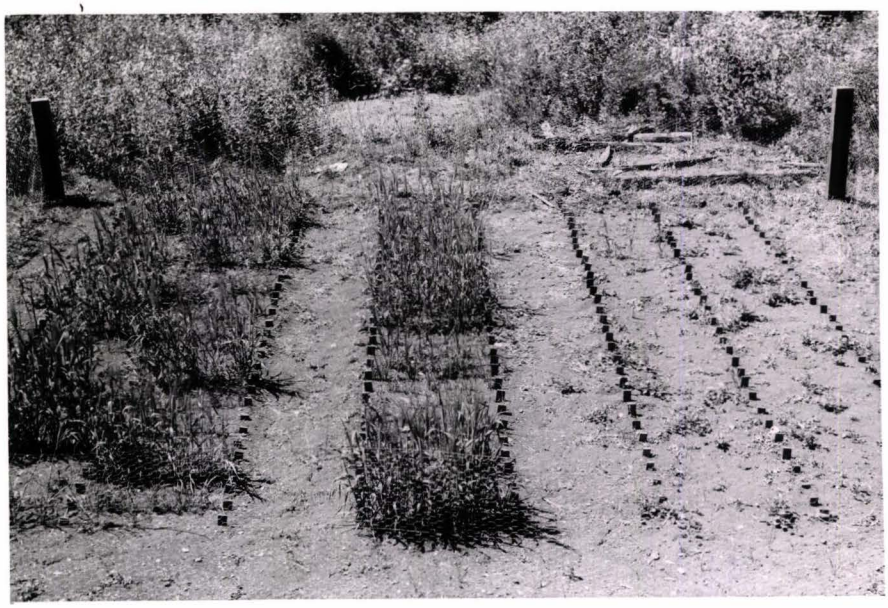
2/ Seed removed on May 25, at 1/2 and 1 inch depths. Depths of 2, 4, and 6, inches, 1 foot and 2 feet were removed on June 1.

3/ Seed removed on June 12, at 1/2, 1, 2, 4, and 6 inch depths. Depths of 1 foot and 2 feet were removed on July 6.

spring or soon after the snow melted. Subsequent counts were made at frequent intervals during the spring period while seedlings were emerging and at selected intervals in the summer and fall to determine mortality. All seedlings were marked with color-coded toothpicks so that development and mortality of individual plants could be followed (figures2 and 3).

As shown in Table 2 , total seedling emergence was greatest from the 1/2 and 1 inch depths. Emergence at the 1/2-inch depth was slower at the 5,500 site than at the 1-inch depth due to the lower temperatures near the soil surface. Frost action was severe at the 7,000 feet site in the spring of 1961, causing soil heaving and crackings as shown in figures4 and 5 . Barley and wild oats that had emerged from the 2- and 4 inch depths during the fall and winter was killed by frost or soil heaving.

Wild oats was the only species emerging from the 6-inch depth at the lower and intermediate site but it did not emerge from this depth at the upper site. Wild oats emerged from the 4-inch depth at all three sites. Other species emerging from the 4-inch depth were 16 percent of the barley seeds and one plant of intermediate wheatgrass at the 7,000 feet site.



Figures 2 and 3. Emergence, development and mortality of seedlings were followed from planting depths of 1/2, 1, 2, 4, and 6 inches. Upper photo shows the study area at 8,850 feet and the lower photo shows the study area at 7,000 feet (61-94 and 61-58).

Table 2 . Average number of seedlings emerging and number of established plants (living)1/ per 100 seeds of 8 species planted at five depths at three locations in the fall of 1960.

Depth (Inches)	Location (Feet)	Species															
		Crested Wheatgrass		Intermediate Wheatgrass		Slender Wheatgrass		Wild Oats		Barley		Mountain Brome		Smooth Brome		Alfalfa	
		emerged	living	emerged	living	emerged	living	emerged	living	emerged	living	emerged	living	emerged	living	emerged	living
1/2	5,500	43	1	44	8	13	1	5	2	60	0	38	4	28	1	2	0
	7,000	62	10	65	38	34	24	10	3	66	59	38	24	26	9	34	1
	8,850	65	15	81	69	76	67	24	7	69	59	88	75	22	5	38	0
1	5,500	36	2	54	12	54	2	44	24	22	6	68	24	20	1	4	0
	7,000	45	10	64	38	60	35	20	13	66	60	53	34	32	13	21	1
	8,850	38	19	72	55	78	70	50	22	65	56	80	71	28	10	32	1
2	5,500	1	0	12	0	10	0	54	29	58	8	16	0	2	0	0	0
	7,000	3	1	14	2	14	2	35	16	70	7	22	7	8	2	0	0
	8,850	4	2	10	8	17	9	43	21	49	30	14	7	6	1	1	0
4	5,500	0	0	0	0	0	0	54	35	0	0	0	0	0	0	0	0
	7,000	0	0	1	0	0	0	31	13	16	3	0	0	0	0	0	0
	8,850	0	0	0	0	0	0	14	5	0	0	0	0	0	0	0	0
6	5,500	0	0	0	0	0	0	58	41	0	0	0	0	0	0	0	0
	7,000	0	0	0	0	0	0	27	13	0	0	0	0	0	0	0	0
	8,850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1/ Living plants counted on September 12, 1961.

Figures 4 and 5. Frost action was severe at the 7,000 feet site in the spring of 1961 killing most of the emerged seedlings and causing soil heaving (61-10 and 61-14).

III-B. Date of planting in the fall at three locations.

Results from date of planting studies established in the fall of 1958 and 1959 were included in the 1959 and 1960 Progress Reports. Only data from the planting made in the fall of 1960 has been included in this report.

This study was established to determine when seeds of four grasses germinate in the fall and winter and to evaluate the advantages and disadvantages of early and late fall seedings. Seed germination in the fall and winter is further evaluated by comparing field germination with laboratory germination at near optimum conditions.

Freshly harvested seed of intermediate wheatgrass, slender wheatgrass, mountain brome, and smooth brome were planted on four dates in the fall at three locations. Sites were located at 5,500 feet, 7,000 feet, and 8,850 feet. Seed units of 100 seeds in nylon bags were planted at all sites on each area on date except that three additional replications were planted on the first date.

Early fall of 1960 was favorable for some seed germination. Snow depth was about 16 inches deep at the upper site when the last seed sample was planted on November 15. The extra replications planted on the first planting date were removed on the last planting date and seed germination was determined. Germination on this seed on November 15 at the three sites ranged between 95 and 99 percent for intermediate wheatgrass; 29 and 46 percent for smooth brome; 0 and 3 percent for slender wheatgrass; and mountain brome seed had not started to germinate.

Seeds planted on each of the four planting dates were removed from each of the three sites on two dates in the spring according to plant

development at the site: (1) early (March 13, March 27, and May 22 respectively) and (2) just as the soil was drying (April 25, June 7, and June 13 respectively). Snow depth ranged from 3 to over 12 inches in depth when the early samples were removed.

Table 3, shows percent seed germination for the four dates of planting when removed from the soil and after 35 additional days in the germinator. Seed dormancy in native slender wheatgrass was not fully broken in the late planting (November 25) at the lower and intermediate sites. Seed germination of mountain brome was similar except that some dormancy was also indicated at the upper site.

Seeds of smooth brome and intermediate wheatgrass that had not germinated prior to removal from the soil were much slower to germinate in the laboratory than fresh seed from identical lots. Many of the smooth brome seeds developed shoots before a radicle or root was visible indicating the primary radicle had been damaged. Most of the intermediate wheatgrass and smooth brome seedling that emerged during the fall, winter, or early spring were damaged or killed by early spring frosts and freezing.

Table 3 . Percent germination from four dates of planting in the fall when seeds were removed at two dates in the spring, depending on climatic conditions at the three sites and after subsequent laboratory germination of 35 days.

	Sorenson's - 5,500 ft.		Majors - 7,000 ft.		Headquarters - 8,850 ft.	
Planting Date	1st 3/13	2nd 4/25	1st 3/27	2nd 6/7	1st 5/22	2nd 6/13
Intermediate wheatgrass - when removed from field						
9/15	93.7	96.0	96.0	97.0	96.7	94.7
10/6	99.0	98.7	98.3	97.3	96.0	95.7
10/26	99.0	96.7	91.3	95.7	93.7	94.3
11/25	49.3	95.0	69.0	96.0	92.3	95.3
- after 35 days in laboratory						
9/15	98.7	96.0	96.0	97.0	97.0	94.7
10/6	99.3	98.7	99.0	97.7	97.7	96.0
10/26	99.0	97.0	95.3	97.3	97.3	96.0
11/25	94.3	96.0	94.0	96.7	97.3	96.7
Slender wheatgrass - when removed from field						
9/15	34.0	70.0	15.0	81.3	91.0	98.7
10/6	20.0	88.0	55.3	91.3	93.0	97.0
10/26	64.3	84.0	35.0	98.3	83.7	96.3
11/25	12.7	26.7	2.0	71.0	73.0	88.7
- after 35 days in laboratory						
9/15	70.0	81.7	74.3	91.7	98.0	99.3
10/6	51.3	90.3	93.3	93.7	99.3	97.7
10/26	81.3	85.3	85.3	98.3	98.0	97.3
11/25	35.7	46.7	45.3	79.0	97.7	96.0
Mountain brome - when removed from field						
9/15	68.3	97.3	90.7	96.7	99.0	98.7
10/6	60.7	99.3	98.0	97.3	98.3	98.0
10/26	91.3	96.0	97.3	95.0	93.3	95.0
11/25	3.3	63.7	7.7	24.7	78.3	88.0
- after 35 days in laboratory						
9/15	89.3	98.0	91.3	96.7	99.3	99.0
10/6	81.3	99.3	98.0	98.3	98.7	98.0
10/26	94.7	96.0	97.3	95.0	93.7	95.3
11/25	19.0	65.7	11.0	25.0	79.3	88.3

Table 3 .--(continued)

	Sorenson's - 5,500 ft.		Majors - 7,000 ft.		Headquarters - 8,850 ft.	
Planting Date	1st 3/13	2nd 4/25	1st 3/27	2nd 6/7	1st 5/22	2nd 6/13
Smooth brome - when removed from field						
9/15	51.7	90.7	44.7	86.3	62.0	78.7
10/6	54.3	84.7	69.7	93.3	29.7	78.7
10/26	47.0	83.0	32.3	86.7	22.0	65.3
11/25	3.7	82.7	19.0	85.3	18.3	68.0
- after 35 days in laboratory						
9/15	88.0	90.7	87.3	90.7	88.7	90.0
10/6	83.7	85.0	88.0	93.3	80.7	86.0
10/26	78.3	83.7	89.7	86.7	77.3	88.0
11/25	72.0	84.7	78.7	86.3	79.0	91.3

III-C. Fungi on seeds of four grasses.

Recent observations have shown that seeds or seedling diseases may seriously reduce seed germination and increase seedling mortality. Information on degree of infection by the fungus Podosporiella verticillata was followed at three elevations in 1958-1959 and 1959-1960. Similar studies were established in the fall of 1960 and additional tests were set up at four additional areas in the sagebrush-grass type.

Seeds were placed in nylon bags with 100 seeds of a single species in each bag. Seed of the susceptible grasses; smooth brome, intermediate wheatgrass, and crested wheatgrass were used at all locations. Seed of the native mountain brome and native slender wheatgrass were also included in a depth of planting study at Sorenson's field.

Seeds were planted between October 26 and October 28, 1960 at all locations. Three replications of each species treated with Orthocide 75 and three replications of natural seed were placed under 3/4 inch of soil, except that additional plantings of the five species were also made at depths of 1/2, 1, 2, 4, 6, 12, and 24 inches at Sorenson's field.

Although early fall temperatures and soil moisture had been favorable for seed germination, air and soil temperatures were low during November and throughout the winter. Seeds were left in the soil until the following spring until residual moisture had been largely depleted.

Seeds in the sagebrush type were removed from the soil during the latter part of April and first part of May. Seed in mountain brush type were removed on June 7 and seed at the aspen-fir site were removed June 13.

Table 4 shows seed treatment with Orthocide 75 was effective in reducing the number of seeds infected with Podosporiella at all locations in the sagebrush type and in mountain brush type. Seeds planted in the aspen-fir type were not infected with this fungi. Seed treatment generally increased total seed germination and total seedling emergence although laboratory studies have shown that seeds treated with Orthocide 75 did not begin to germinate as rapidly as untreated seed.

Percent of seeds infected with this fungi varied from site to site in the sagebrush type. As in previous studies smooth brome seed was damaged more than crested wheatgrass or intermediate wheatgrass seed. Figures 6 and 7 show the 6-mile area where 75 percent of the smooth brome seed was infected with Podosporiella. Untreated seeds of crested wheatgrass, smooth brome, and intermediate wheatgrass infected with this fungi can be seen in the lower nylon bag in figure 8 .

As shown in Table 5 , numbers of seeds infected at depths of 1/2, 1, 2, and 4 inch depths were similar. Percent of seeds infected at 6, 12, and 24 inches decreased with depth. However in both 1958-1959 and 1959-1960 infection had been relatively high at the 24 inch depth.

During the fall of 1961, additional plantings were made in the sagebrush type in Utah and in the surrounding states. Several plantings were made near Logan, Utah. Other plantings in Utah were

Table 4. A comparison of number of seeds infected with Podosporiella verticillata; germination, emergence, and good seed remaining in natural seed of three grasses compared with seed treated with Orthocide 75.

Species	Seed Treatment	Seeds Infected	Germinated	Emerged	Good Seed
		Percent			
6-Mile - 6,000 ft.					
Crested wheatgrass	None	57.3	75.7	11.3	0.0
	Orthocide	0.0	79.0	28.3	13.0
Intermediate wheatgrass	None	45.7	85.7	31.3	0.0
	Orthocide	0.0	96.0	47.0	1.0
Smooth brome	None	75.0	32.0	5.3	0.0
	Orthocide	0.3	79.0	34.0	13.3
Benmore - 5,800 ft.					
Crested wheatgrass	None	3.7	94.0	40.7	0.0
	Orthocide	0.0	87.3	62.0	2.3
Intermediate wheatgrass	None	1.3	92.0	44.0	0.0
	Orthocide	0.3	93.0	64.3	0.7
Smooth brome	None	36.0	54.0	10.3	0.0
	Orthocide	0.0	84.3	27.0	1.7
Rasmusson's Farm - 5,700 ft.					
Crested wheatgrass	None	20.0	88.7	41.7	0.0
	Orthocide	0.0	78.7	52.7	11.3
Intermediate wheatgrass	None	11.3	91.7	62.0	0.0
	Orthocide	0.0	98.0	76.7	0.0
Smooth brome	None	23.0	63.3	26.0	0.0
	Orthocide	0.0	82.7	51.7	2.7
Fairview - 6,100 ft.					
Crested wheatgrass	None	1.3	88.0	48.3	0.0
	Orthocide	0.0	83.0	60.7	2.0
Intermediate wheatgrass	None	0.7	96.7	80.3	0.0
	Orthocide	0.0	95.7	79.0	0.0
Smooth brome	None	2.7	77.7	46.0	0.0
	Orthocide	0.0	75.3	26.0	1.3
Sorenson's Field - 5,500 ft.					
Crested wheatgrass	None	27.0	94.7	4.0	0.0
	Orthocide	0.0	85.3	6.0	2.7
Intermediate wheatgrass	None	30.3	95.3	3.0	0.0
	Orthocide	0.0	99.0	18.3	0.0
Smooth brome	None	42.3	74.7	5.3	0.0
	Orthocide	0.0	79.7	36.3	7.7

Table 4 .(continued)

Species	Seed Treatment	Seeds Infected	Germinated	Emerged	Good 1/ Seed
		Percent			
Majors Flat - 7,000 ft.					
Crested wheatgrass	None	2.7	89.7	11.3	1.3
	Orthocide	0.0	89.0	12.3	3.7
Intermediate wheatgrass	None	1.0	96.7	61.3	0.0
	Orthocide	0.0	95.7	73.0	0.0
Smooth brome	None	2.7	77.0	16.3	1.0
	Orthocide	0.0	86.7	41.7	5.7
Headquarters - 8,850 ft.					
Crested wheatgrass	None	0.0	93.7	3.3	0.7
	Orthocide	0.0	86.0	13.7	3.0
Intermediate wheatgrass	None	0.0	90.3	22.3	0.0
	Orthocide	0.0	96.0	52.7	1.0
Smooth brome	None	0.0	68.0	9.0	0.0
	Orthocide	0.0	88.0	7.7	5.3

1/ Seeds were firm and appeared to be good(viable) at the end of the 35-day laboratory germination period.

Figures 6 and 7. Photos show the planting site in 6-mile Canyon where infection of untreated seed by Podosporiella was relatively high (61-19 and 61-20).

Figure 8 . Treated seeds of crested wheatgrass, intermediate wheatgrass, and smooth brome in the upper bags and natural seed in the lower bags were removed from 6-mile Canyon in the spring of 1961. The black fungi protruding from the lower bags had infected an average of 57.3, 45.7, and 75.0 percent of the untreated seeds (61-26).

Table 5 . Percent of seeds of five species planted at seven depths in the fall of 1960 that were visibly infected with Podosporiella verticillata in the spring of 1961.

Species	Depth of Planting 1/2 inch	1 inch	2 inch	4 inch	6 inch	12 inch	24 inch	Average
	Percent							
Desert wheatgrass	32.0	27.0	13.0	13.7	8.3	5.3	3.0	14.6
Intermediate wheatgrass	20.7	30.3	23.3	26.3	15.0	8.0	3.7	18.2
Slender wheatgrass	0.0	2.0	3.0	1.0	1.0	3.0	0.0	1.4
Mountain brome	3.0	9.0	2.0	10.0	6.0	2.0	3.0	5.0
Smooth brome	39.7	42.3	33.0	47.0	27.3	22.7	8.0	31.4
Average	19.1	22.1	14.9	19.6	11.5	8.2	3.5	14.1

made near Ephraim, Benmore, Richfield, Cove Fort, and Beaver. Plantings in the surrounding states were made by L.O. Hylton in California, R.E. Eckert in Nevada, G. Klomp in Idaho, F.B. Gomm in Montana, F.A. Sneva in Oregon, and D.H. Gates in Washington. Seed removed from the Logan area in the late fall of 1961 show some seed infected at all planting sites. Results from other areas will not be known until the seeds have been removed in late May or early June of 1961.

III-D. Seed germination and seedling emergence studies at high elevations.

During the fall of 1960 seed of 67 species or strains were planted in rows to follow seedling emergence and seedling mortality. The same species and strains were also placed in bags and planted so that seed germination could be followed. These studies were similar to studies made in the fall of 1958 with 36 species or strains and with 45 species or strains in 1959. Areas used for the germination study were staked with poles over 8 feet tall so that samples could be located after deep snow covered the ground. Areas used for the seedling emergence study were adjacent to the areas planted in the fall of 1958 and 1959.

Seeds used were freshly harvested from the 1960 crop except that two year old seed lots of intermediate wheatgrass, slender wheatgrass, mountain brome, smooth brome, barley, and alfalfa were also included in this study. Where practical seeds were harvested from high elevation areas similar to the study sites. Species used and pertinent information on date and seed source are included in Table 6 .

Laboratory germination tests at 68 and 82° F. were made on all seed lots on September 29, 1960 and again on July 28, 1961 after seeds were about one year old. All seed lots were treated with Orthocide 75, according to directions, prior to placement in the germinator since mold had developed on seeds of many species in earlier tests. Tests were made to determine the difference in seed germination soon after harvest and germination after dry storage for about one year. Laboratory seed germination tests were also used as a control lot for the seeds planted in germination and emergence studies.

Table 6 . Percent germination for seeds of 67 species or strains from 3 planting treatments on Philadelphia Flat(under 3/4 inch of soil after permenent winter snow or ced on the soil surface after permenent snow) on May 28, 1961, just before snowmelt in the following spring.

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow Soil	Permanent Snow Snow	Check Lot 2/ I	Check Lot 3/ II
Grasses						
Agropyron desertorum - Majors Flat. Aug. 5, 1960. El. 7,100 ft.	Removed	91.0	87.0	81.0	-	-
	Final	91.0	87.0	82.0	91.3	94.7
Agropyron intermedium - Frischknecht Farm Aug. 5, 1958. El. 5,500 ft.	Removed	78.0	25.0	82.0	-	-
	Final	79.0	28.0	93.0	99.3	99.0
Agropyron intermedium - Frischknecht Farm Aug. 24, 1960. El. 5,500 ft.	Removed	94.0	31.0	67.0	-	-
	Final	94.0	31.0	75.0	99.3	98.3
Agropyron repens - Ephraim Aug.10, 1960. El. 5,500 ft.	Removed	93.0	44.0	45.0	-	-
	Final	95.0	48.0	69.0	98.0	97.7
Agropyron spicatum - Majors Flat Aug. 4, 1960. El. 7,000 ft.	Removed	97.0	57.0	84.0	-	-
	Final	98.0	57.0	84.0	93.7	98.0
Agropyron trachycaulum - Ephraim Canyon Aug. 14, 1958. El. 9,400 ft.	Removed	83.0	31.0	17.0	-	-
	Final	83.0	33.0	55.0	80.3	95.0
Agropyron trachycaulum - Philadelphia Flat Aug. 22, 1960. El. 10,000 ft.	Removed	72.0	12.0	2.0	-	-
	Final	74.0	16.0	62.0	63.7	50.0
Agropyron trichophorum - Majors Flat Aug. 8, 1960. El. 7,100 ft.	Removed	92.0	5.0	60.0	-	-
	Final	93.0	6.0	70.0	95.7	94.7
Agropyron spp. (Artic)	Removed	93.0	63.0	40.0	-	-
	Final	94.0	74.0	82.0	99.3	98.3
Alopecurus pratensis - Summit Enclosure Aug. 11, 1960. El. 10,200 ft.	Removed	88.0	55.0	45.0	-	-
	Final	91.0	92.0	94.0	88.0	96.0
Arrhenatherum elatius - Summit Enclosure Aug. 18, 1960. El. 10.200 ft.	Removed	93.0	95.0	86.0	-	-
	Final	93.0	95.0	87.0	81.3	83.3
Avena fatua - Silers Farm July 11, 1960. El. 5,500 ft.	Removed	22.0	30.0	0.0	-	-
	Final	22.0	30.0	0.0	35.3	41.3
Hordeum (Barley) - Winter Club Commercial	Removed	99.0	90.0	83.0	-	-
	Final	99.0	90.0	83.0	96.3	98.3

Table 6 .--(continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow Soil	Permanent Snow Snow	Check Lot 2/ I	Check Lot 3/ II
Bromus carinatus - Cattle Pasture Aug. 14, 1958. El. 10,100 ft.	Removed	96.0	84.0	8.0	-	-
	Final	96.0	84.0	17.0	64.3	65.0
Bromus carinatus - 1960 Meadows Aug. 29, 1960. El. 9,900 ft.	Removed	96.0	70.0	9.0	-	-
	Final	96.0	71.0	9.0	0.0	21.7
Bromus inermis - Headquarters Station Sept. 8, 1958. El. 8,850 ft.	Removed	78.0	9.0	17.0	-	-
	Final	78.0	20.0	44.0	92.7	93.3
Bromus inermis - Headquarters Station Aug. 30, 1960. El. 8,850 ft.	Removed	24.0	3.0	16.0	-	-
	Final	27.0	6.0	55.0	82.0	86.7
Bromus tomentellus - Summit Enclosure Aug. 27, 1960. El. 10,200 ft.	Removed	66.0	16.0	28.0	-	-
	Final	66.0	17.0	29.0	90.3	92.3
Dactylis glomerata - Dry Pole Canyon Aug. 29, 1960. El. ,100 ft.	Removed	86.0	70.0	72.0	-	-
	Final	87.0	73.0	80.0	72.7	73.3
Elymus junceus - Majors Flat Aug. 4, 1960. El. 9,100 ft.	Removed	95.0	8.0	68.0	-	-
	Final	95.0	8.0	68.0	99.7	94.7
Festuca ovina - Summit Enclosure Aug. 19, 1960. El, 10,200 ft.	Removed	25.0	0.0	0.0	-	-
	Final	28.0	31.0	91.0	100.0	99.7
Hesperochloa kingi - Buck Ridge Aug. 15, 1960. El. 9,700 ft.	Removed	72.0	26.0	9.0	-	-
	Final	73.0	26.0	90.0	84.3	91.0
Phalaris arundinacea - Bluebell Aug. 22, 1960. El. 9,000 ft.	Removed	3.0	0.0	0.0	-	-
	Final	93.0	85.0	99.0	96.3	92.0
Phleum pratense - Bluebell Aug. 19, 1960. El. 9,000 ft.	Removed	57.0	53.0	46.0	-	-
	Final	99.0	98.0	98.0	53.3	97.3
Stipa columbiana - Cattle Pasture Aug. 22, 1960. El. 10,100 ft.	Removed	60.0	0.0	0.0	-	-
	Final	60.0	71.0	47.0	3.7	4.0
Stipa lettermani - Summit Sept. 4, 1960. El. 10,200 ft.	Removed	86.0	83.0	0.0	-	-
	Final	87.0	95.0	95.0	5.0	8.3

Table 6 .--(continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow Soil	Check Snow	Check Lot2/ I	Check Lot3/ II
Forbs and Shrubs						
Agastache urticifolia - Simpler's Bridge Ephraim Canyon, Aug. 15, 1960. El. 9,700ft.	Removed	43.0	93.0	82.0	-	-
	Final	64.0	94.0	83.0	18.3	12.7
Aquilegia coerulea - Philadelphia Flat Aug. 5, 1960. El. 10,000 ft.	Removed	0.0	0.0	0.0	-	-
	Final	95.0	98.0	100.0	91.0	89.3
Artemisia discolor - Left Hand Fork Sept. 9, 1960. El. 10,200 ft.	Removed	0.0	1.0	4.0	-	-
	Final	17.0	80.0	96.0	56.0	70.3
Caltha leptosepala - Meadows Aug. 25, 1960. El. 9,900 ft.	Removed	51.0	76.0	86.0	-	-
	Final	52.0	81.0	93.0	1.3	0.3
Castilleja sulphrea - Cattle Pasture Sept. 5, 1960. El. 10,100 ft.	Removed	6.0	59.0	46.0	-	-
	Final	6.0	61.0	47.0	0.3	0.0
Claytonia lanceolata - Philadelphia Flat June 27, 1960. El. 10,000 ft.	Removed	68.0	80.0	87.0	-	-
	Final	68.0	81.0	87.0	0.0	0.0
Chrysothamnus viscidflorus- Alpine Summit Sept. 12, 1960. El. 10,200 ft.	Removed	98.0	94.0	91.0	-	-
	Final	98.0	97.0	91.0	63.0	61.0
Collomia linearis - Philadelphia Flat Aug. 8, 1960. El. 10,000 ft.	Removed	17.0	77.0	64.0	-	-
	Final	18.0	77.0	64.0	0.0	0.0
Dephinium barbeyi - Philadelphia Flat Sept. 5, 1960. El. 10,000 ft.	Removed	91.0	91.0	79.0	-	-
	Final	91.0	92.0	81.0	0.0	0.0
Delphinium nelsonii - Philadelphia Flat July 21, 1960. El. 10,000 ft.	Removed	72.0	97.0	93.0	-	-
	Final	72.0	97.0	93.0	0.0	0.0
Descurainia richardsonii - Meadows Aug. 8, 1960. El. 9,900 ft.	Removed	18.0	8.0	9.0	-	-
	Final	18.0	19.0	17.0	0.7	1.0
Eriogonum neglectum - Philadelphia Flat Aug. 21, 1960. El. 10,000 ft.	Removed	52.0	91.0	92.0	-	-
	Final	54.0	92.0	95.0	14.0	3.7
Frythronium grandiflorum - Cattle Pasture Aug. 3, 1960. El. 10,100 ft.	Removed	98.0	95.0	52.0	-	-
	Final	98.0	95.0	52.0	0.0	0.0

Table 6 .--(continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow: Soil	Permanent Snow: Snow	Check Lot2/ I	Check Lot3/ II
Geranium richardsonii - Philadelphia Flat	Removed	98.0	95.0	90.0	-	-
Aug. 16, 1960. El. 10,000 ft.	Final	98.0	97.0	94.0	55.7	42.3
Gilia pulchella - Cattle Pasture	Removed	6.0	63.0	13.0	-	-
Aug. 8, 1960. El. 10,100 ft.	Final	6.0	63.0	13.0	5.0	4.0
Lesquerella utahensis - Alpine Summit	Removed	40.0	0.0	0.0	-	-
July 21, 1960. El. 10,200 ft.	Final	51.0	11.0	18.0	23.3	22.7
Ligusticum porteri - Cattle Pasture	Removed	78.0	71.0	38.0	-	-
Aug. 23, 1960. El. 10,100 ft.	Final	79.0	74.0	38.0	0.0	0.0
Lomatium nuttallii - Cattle Pasture	Removed	47.0	44.0	23.0	-	-
Aug. 16, 1960. El. 10,100 ft.	Final	47.0	44.0	23.0	0.0	0.0
Lupinus alpestris - Summit Enclosure	Removed	31.0	93.0	90.0	-	-
Aug. 16, 1960. El. 10,200 ft.	Final	31.0	93.0	92.0	46.3	29.7
Madia glomerata - Philadelphia Flat	Removed	68.0	80.0	99.0	-	-
Sept. 4, 1960. El. 10,000 ft.	Final	93.0	95.0	99.0	0.0	0.0
Mertensia leonardi - Philadelphia Flat	Removed	90.0	80.0	68.0	-	-
July 21, 1960. El. 10,000 ft.	Final	91.0	83.0	71.0	3.3	1.3
Medicago sativa (Rambler) Commercial	Removed	80.0	88.0	84.0	-	-
	Final	82.0	91.0	85.0	80.7	82.0
Orthocarpus tolmiei - Meadow	Removed	24.0	65.0	64.0	-	-
Aug. 21, 1960. El. 9,900	Final	24.0	65.0	64.0	0.0	0.0
Osmorhiza occidentalis - Philadelphia Flat	Removed	94.0	91.0	91.0	-	-
Aug. 17, 1960. El. 10,000 ft.	Final	97.0	91.0	91.0	0.0	0.0
Penstemon rydbergii - Philadelphia Flat	Removed	58.0	66.0	66.0	-	-
Sept. 5, 1960. El. 10,000 ft.	Final	61.0	95.0	67.0	0.0	1.3
Polygonum douglasii - Philadelphia Flat	Removed	12.0	86.0	96.0	-	-
Aug. 9, 1960. El. 10,000 ft.	Final	12.0	86.0	96.0	0.0	0.0

Table 6 .--(continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow: Soil	Permanent Snow: Snow	Check Lot2/ I	Check Lot3/ II
Polemonium foliosissimum- Philadelphia Flat Aug. 26, 1960. El. 10,000 ft.	Removed	89.0	73.0	0.0	-	-
	Final	90.0	78.0	3.0	0.0	0.7
Potentilla glandulosa - Philadelphia Flat Aug. 8, 1960. El. 10,000 ft.	Removed	12.0	27.0	74.0	-	-
	Final	14.0	71.0	92.0	0.0	0.0
Potentilla pulcherrima - Philadelphia Flat Aug. 21. 1960. El. 10,000 ft.	Removed	0.0	0.0	1.0	-	-
	Final	89.0	97.0	99.0	92.7	92.0
Pseuducymopterus montanus - Summit Aug. 2, 1960. El. 10,200 ft.	Removed	3.0	0.0	0.0	-	-
	Final	94.0	45.0	86.0	86.0	91.7
Ribes inebrians - Alpine Summit Aug. 29, 1960. El. 10,200 ft.	Removed	86.0	25.0	43.0	-	-
	Final	86.0	25.0	46.0	0.0	0.0
Ribes montigenum - Philadelphia Flat Aug. 14, 1960. El. 10,000 ft.	Removed	18.0	33.0	33.0	-	-
	Final	19.0	34.0	34.0	0.0	0.0
Rudbeckia occidentalis - Simpler's Bridge Sept. 9, 1960. El. 9,700 ft.	Removed	0.0	0.0	0.0	-	-
	Final	98.0	98.0	99.0	90.3	94.7
Rumex mexicanus - Philadelphia Flat Sept. 25, 1960. El. 10,000 ft.	Removed	0.0	0.0	0.0	-	-
	Final	86.0	9.0	85.0	21.3	0.7
Sambucus racemosa - Meadows Aug. 15, 1960. El. 9,900 ft.	Removed	4.0	2.0	8.0	-	-
	Final	5.0	4.0	14.0	0.0	0.0
Stellaria jamesiana - Philadelphia Flat Aug. 11, 1960. El. 10,000 ft.	Removed	57.0	75.0	81.0	-	-
	Final	57.0	75.0	85.0	1.0	1.0
Taraxacum officinale - Philadelphia Flat July 18, 1960. El. 10,000 ft.	Removed	13.0	3.0	9.0	-	-
	Final	83.0	13.0	77.0	93.3	96.0
Valeriana edulis - Cattle Pasture Aug. 11, 1960. El. 10,100 ft.	Removed	0.0	0.0	0.0	-	-
	Final	100.0	98.0	99.0	39.7	49.7
Viguiera multiflora - Headquarters Sept. 9, 1960. El. 8,850 ft.	Removed	21.0	36.0	11.0	-	-
	Final	43.0	44.0	15.0	0.0	0.7

Table 6 .--(continued)

Species, Location, and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow Soil	Permanent Snow Snow	Check Lot2/ I	Check Lot3/ II
Viola nuttallii linguaefolia - Philadelphia Flat. July 22, 1960. El. 10,000 ft.	Removed	82.0	88.0	62.0	-	-
	Final	83.0	88.0	62.0	0.0	0.0
Zigadenus elegans - Philadelphia Flat Aug 25, 1960. El. 10,000 ft.	Removed	80.0	84.0	88.0	-	-
	Final	88.0	99.0	100.0	99.7	94.0

1/ Removed from soil and snow on May 28, 1961 and Final after laboratory germination for 30 days.

2/ Check Lot in germinator on 9-29-60.

3/ Check Lot in germinator on 7-28-61.

Plantings were made on two areas less than 2 miles apart, but slope and exposure are quite different: (1) Philadelphia Flat is located on a wide, near level terrace at an elevation of approximately 10,000 feet. This area is frequently covered with snow from the first heavy snow in October or November until the air temperature is relatively high the following May or early June, when frost danger is low. This area is subjected to flooding during rapid snowmelt in the spring. Flooding has also caused a breakdown in the soil structure, which in turn has decreased soil aeration, reduced water holding capacity, and favored crusting. (2) Summit Enclosure is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth, during the winter period, is usually less than on Philadelphia Flat, due to increased melting in the fall and spring, and wind action. Soil may be frozen during the winter. When the soil has been bare or snow covering has been shallow, alternate freezing and thawing has produced heaving, frost damage, or rapid drying of the surface soil aroung the seeds. Flooding has been observed, but does not appear to be a serious problem on this site.

About 9 inches of snow fell at high elevations on October 10 but it was largely gone by October 31. Low temperatures in late October caused severe frost action and the soil was frozen to a depth of about 1 inch. Additional snow fell in early November and snow depth was 19 inches deep on November 30. Additional snow fell in early December bringing average snow depth to about 22 inches. Clear skies, low temperatures, and relatively shallow snow depth during December and January resulted in freezing of the soil to depth of 3 to 6 inches. Snow depth at

Philadelphia Flat increased to 64 inches in March and remained over 4 feet deep until the middle of May. Snow on the Summit plot melted on May 22 and snow on Philadelphia Flat melted during the period May 28 to June 1, 1961.

This study was divided into two phases. In one phase, the germination of seeds in nylon bags, planted under snow or soil, on two dates of planting was checked at intervals during the winter and spring. In the second phase, seed of each species was planted in rows in the fall, and emergence and mortality counts were made at intervals during the following spring and summer.

One hundred seeds of a single species were placed in nylon bags and the bags were closed and stitched. Large seeds were placed in bags with a mesh opening about 1/20-inch square. Species with small seeds were placed in bags made from light weight nylon material with a fine mesh.

Early fall plantings of seeds in nylon bags were made under 3/4 inch of soil on September 22 at both Summit and Philadelphia Flat. Plantings were also made on November 6 after the area was covered with snow. Snow depth averaged 12 inches at Summit and 14 inches at Philadelphia Flat. Part of the bags were placed on the soil surface and part were placed at a depth of 3/4 inch below the soil surface. The original snow cover was replaced after planting.

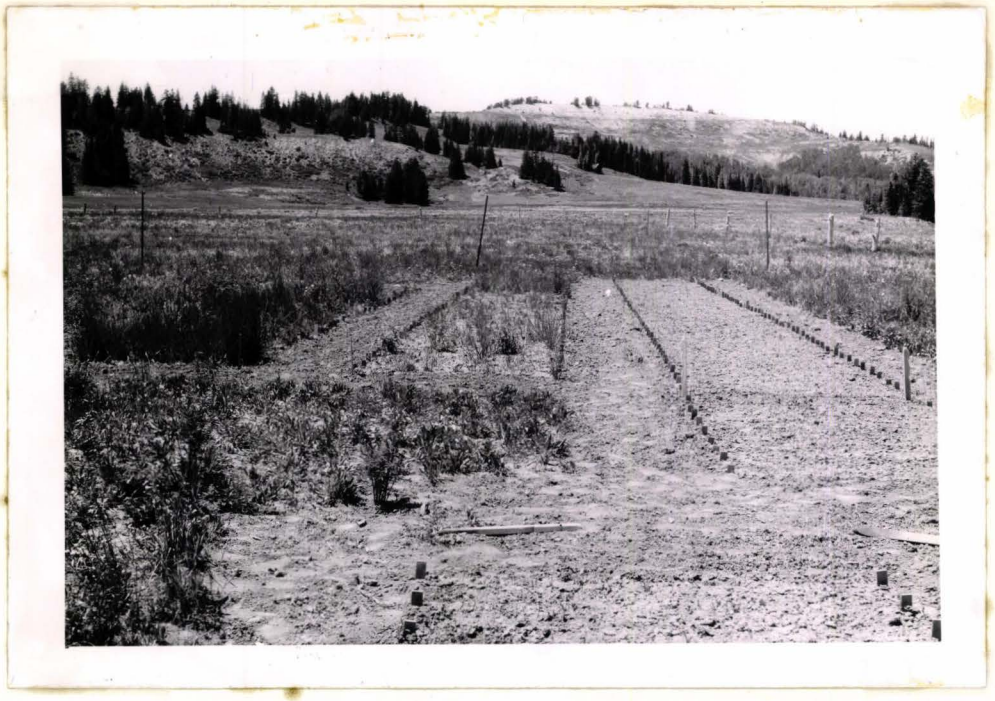
One series of bags planted on September 22 was removed from each area on November 6 so that seed germination in the fall could be determined. Subsequent removal of seed from Philadelphia Flat and Summit was made when snow was 64 inches deep, just a few days before the snow melted in the spring (figures 9 and 10), and just as the soil was drying in the early summer.

Figures 9 and 10. Seeds in nylon bags were removed from Philadelphia Flat just before the snow melted in the spring of 1961 (61-50 and 61-54).

Seed germination in the check lots placed in the germinators on September 29, 1960 and July 28, 1961 and field germination in the sample removed from Philadelphia Flat on May 28, 1961 just before spring snowmelt, are shown in Table 6 . All but 6 of the 67 seed lots in the early (pre-snow) planting had started to germinate when the seeds were removed from the soil. Fifty-seven of the seed lots planted under 3/4 inch of soil after the ground was snow covered were germinating prior to spring snowmelt. In general, germination of seed placed on the soil surface under the snow cover was less than comparable seed lots placed under 3/4 inch of soil on the same planting date.

In the second phase of this study seedling emergence and seedling mortality was followed during the summer. Fall plantings with 100 seeds of each species replicated three times were made at the Summit on September 19 and at Philadelphia Flat on September 21. All species were planted at random, except that the 1958 and 1960 seeds of intermediate wheatgrass, smooth brome, slender wheatgrass and mountain brome were planted in adjoining rows. Each row was 5 feet long. Large seeds were planted at a maximum depth of 2 cm and small seeds were planted at a maximum depth of 1cm. Additional plantings at Philadelphia Flat were made on June 2, 1961. This spring planting differed from the fall plantings in that 50 seeds were planted in rows 30 inches long.

Seedling emergence and seedling mortality counts were made on each area just after snowmelt and about June 5, June 9, June 13, June 21, July 6, July 13, August 3, and September 11. On each date the newly emerged seedlings were marked with color-coded toothpicks (figure 11). Average seedling emergence just after snowmelt, in



Figures 11 and 12. Emerged seedlings were counted and marked with color-coded toothpicks so that date of emergence and mortality could be followed (61-66). The lower photo shows seedling and mortality counts made during the second growing season (61-147).

midsummer and in the early fall are shown in Table 7 .

In general, the grasses produced better stands than the forbs. All grass species produced some seedlings at both sites. Three forbs and the shrub failed to emerge at Philadelphia Flat. Four forbs failed to emerge at the Summit Enclosure.

Additional mortality in the 1960 planting had usually occurred when counts were made in the second growing season (figure 12). In general, mortality of grass plants was less than for the forbs. Seedlings from seed planted in the fall of 1959 were counted in the second growing. Species producing the most seedlings in the second year were Bromus carinatus, Agropyron trachycaulum, Delphinium nelsonii, Frythronium grandiflorum, Lomatium nuttallii, Osmorhiza occidentalis, Penstemon rydbergii, Stellaria jamesiana, Valeriana edulis, and Viola nuttallii. Annual species suce as Collomia, Madia, and Polygonium produced abundant plants in the second growing season from seed produced the first growing season.

This study has shown that conditions necessary for seed germination vary with species. Seeds of some of the domestic grasses, crested wheatgrass, intermediate wheatgrass, and smooth brome in particular, began to germinate as soon as moisture was adequate, even though temperatures around the seed often went below freezing at night. Seeds of some native and introduced grasses and forbs were slower to begin germinating under the low night temperatures and limited moisture. Typical of these species were Alopecurus, orchardgrass, Geranium, and lupine. Seed germination in many other native plants remained low until seed dormancy was broken by the cold moist conditions existing

Table 7 . Average field emergence per 100 fall planted seeds and seedling mortality at two locations on three dates; after spring snowmelt(5-31 or 6-2), mid-summer(7-6 or 7-10), and early fall(9-11 or 9-12-1960)

Species		Location					
		Philadelphia Flat			Summit Enclosure		
		Spring	Summer	Fall	Spring	Summer	Fall
Grasses		6/2	7/10	9/12	5/31	7/6	9/11
Agropyron desertorum	Emergence	11.3	28.7	28.7	35.3	54.7	54.7
	Mortality		17.7	20.7		24.3	32.0
Agropyron intermedium 1958	Emergence	4.3	21.3	23.3	33.7	65.7	65.7
	Mortality		10.0	11.0		14.3	22.3
Agropyron intermedium 1960	Emergence	7.3	19.0	19.0	25.7	59.7	59.7
	Mortality		9.3	10.7		14.3	21.0
Agropyron repens	Emergence	1.3	11.3	11.3	3.0	41.0	41.0
	Mortality		5.3	6.3		11.3	16.7
Agropyron spicatum	Emergence	4.3	15.7	15.7	20.0	57.3	57.3
	Mortality		5.0	5.7		13.3	14.7
Agropyron trachycaulum 1958	Emergence	5.0	26.3	26.3	6.3	58.3	58.7
	Mortality		4.0	6.7		7.0	11.7
Agropyron trachycaulum 1960	Emergence	0.0	30.0	30.0	0.7	62.0	62.0
	Mortality		4.0	6.7		7.7	10.3
Agropyron trichophorum	Emergence	3.7	16.0	16.0	11.0	55.0	55.0
	Mortality		9.7	10.7		13.3	25.3
Agropyron Spp.	Emergence	3.5	27.5	27.5	—	—	—
	Mortality		8.0	11.5		—	—
Alopecurus pratensis	Emergence	3.3	8.7	9.0	8.0	41.0	41.0
	Mortality		6.7	8.3		33.0	35.3
Arrhenatherum elatius	Emergence	12.0	35.3	35.3	3.3	47.3	48.3
	Mortality		20.7	26.0		25.0	30.7
Avena fatua	Emergence	0.0	16.0	19.0	0.0	0.7	0.7
	Mortality		6.7	7.3		0.0	0.0

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Table 7 .--(continued)

Species		Location: Philadelphia Flat 6/2	Philadelphia Flat 7/10	Philadelphia Flat 9/12	Summit Enclosure 5/31	Summit Enclosure 7/6	Summit Enclosure 9/11
Hordeum (Barley)	Emergence	0.7	1.3	1.3	36.0	47.0	47.0
	Mortality		0.7	0.7		26.3	29.7
Bromus carinatus 1958	Emergence	3.0	29.7	29.7	0.0	50.0	50.0
	Mortality		9.3	13.7		14.3	20.0
Bromus carinatus 1960	Emergence	0.7	27.3	32.7	0.7	34.3	34.3
	Mortality		7.0	8.7		11.0	14.0
Bromus inermis 1958	Emergence	3.3	10.7	10.7	4.0	42.0	42.0
	Mortality	[illegible]	6.3	6.3		30.0	30.0
Bromus inermis 1960	Emergence	1.0	5.0	5.3	0.7	33.7	33.7
	Mortality		3.0	3.3		20.7	21.7
Bromus tomentellus	Emergence	0.3	11.0	11.0	3.3	51.3	51.3
	Mortality		5.3	6.0		13.7	22.7
Dactylis glomerata	Emergence	0.0	5.3	5.3	3.0	37.3	37.3
	Mortality		3.7	3.7		22.7	28.0
Elymus junceus	Emergence	3.0	15.3	18.7	6.7	36.0	36.0
	Mortality		7.7	10.0		18.3	24.0
Festuca ovina	Emergence	0.0	2.7	2.7	0.0	12.3	12.3
	Mortality		0.7	0.7		8.7	10.0
Hesperochloa kingi	Emergence	0.0	15.0	15.0	0.3	48.3	48.3
	Mortality		10.3	11.7		29.3	35.3
Phalaris arundinacea	Emergence	0.0	3.7	3.7	0.3	33.7	33.7
	Mortality		1.7	1.7		29.0	33.0
Phleum pratense	Emergence	0.7	9.7	9.7	1.3	40.3	40.3
	Mortality		7.0	7.7		38.3	38.3

Table 7 .--(continued)

Species		Location: Philadelphia Flat 6/2	Philadelphia Flat 7/10	Philadelphia Flat 9/12	Summit Enclosure 5/31	Summit Enclosure 7/6	Summit Enclosure 9/11
Stipa columbiana	Emergence	0.0	12.3	12.3	1.3	36.0	36.0
	Mortality		3.7	3.7		6.0	9.3
Stipa lettermani	Emergence	0.0	30.3	30.3	0.0	65.3	65.3
	Mortality		10.3	15.0		6.7	10.7
Forbes and Shrubs							
Agastache urticafolia	Emergence	0.0	3.7	3.7	1.0	44.7	44.7
	Mortality		2.7	2.7		33.0	33.7
Aquilegia coerulea abliflora	Emergence	0.0	0.0	0.0	0.3	0.3	0.3
	Mortality		0.0	0.0		0.3	0.3
Artemisia discolor	Emergence	0.0	0.3	0.3	0.3	11.0	11.0
	Mortality		0.0	0.3		11.0	11.0
Caltha leptosepala	Emergence	0.0	0.7	0.7	0.0	3.0	3.0
	Mortality		0.7	0.7		3.0	3.0
Castilleja sulphurea	Emergence	0.0	0.0	0.0	—	—	—
	Mortality		0.0	0.0		—	—
Claytonia lanceolata	Emergence	54.3	62.0	62.0	2.0	11.3	11.3
	Mortality		62.0	62.0		11.3	11.3
Chrysothamnus viscidiflorus	Emergence	0.0	0.0	0.0	14.0	24.0	24.0
	Mortality		0.0	0.0		22.0	22.3
Collomia linearis	Emergence	17.0	24.7	24.7	19.0	43.3	43.3
	Mortality		11.0	13.3		29.0	29.3
Delphinium barbeyi	Emergence	0.7	8.0	8.0	0.3	12.7	12.7
	Mortality		8.0	8.0		12.3	12.7
Delphinium nelsoni	Emergence	21.3	59.0	59.0	1.3	30.3	30.3
	Mortality		53.0	59.0		26.7	30.3

Table 7 .--(continued)

Species		Location: Philadelphia Flat			Location: Summit Enclosure		
		6/2	7/10	9/12	5/31	7/6	9/11
Descurainia richardsonii			16.0	16.0	11.7	23.7	23.7
	Mortality		12.7	14.0		22.7	23.0
Eriogonum neglectum	Emergence	0.0	31.7	31.7	41.7	87.0	87.0
	Mortality		12.3	13.0		44.0	46.3
Erythronium grandiflorum	Emergence	18.7	81.3	81.3	0.0	6.0	6.0
	Mortality		81.3	81.3		6.0	6.0
Geranium richardsonii	Emergence	0.0	43.0	41.0	10.3	57.3	57.3
	Mortality		20.3	23.0		36.7	38.0
Gilia pulchella	Emergence	0.0	10.0	10.0	—	—	—
	Mortality		7.0	7.0		—	—
Lesquerella utahensis	Emergence	0.0	0.0	0.0	2.0	13.7	13.7
	Mortality		0.0	0.0		10.0	13.7
Ligusticum porteri	Emergence	0.0	42.7	42.7	0.0	7.3	7.3
	Mortality		29.0	32.7		5.7	6.3
Lomatium nuttallii	Emergence	1.7	32.7	34.7	0.0	19.3	19.3
	Mortality		16.7	18.0		14.0	15.0
Lupinus alpestris	Emergence	5.0	54.0	54.0	36.7	52.0	52.0
	Mortality		29.0	37.7		22.0	28.7
Madia glomerata	Emergence	22.0	44.3	44.3	25.0	42.0	42.0
	Mortality		21.3	22.7		29.3	30.3
Mertensia leonardi	Emergence	1.0	25.3	25.3	14.7	40.7	40.7
	Mortality		19.3	23.3		39.3	40.7
Medicago sative	Emergence	1.3	3.0	8.7	27.3	38.7	38.7
	Mortality		3.0	3.0		33.0	34.0

Table 7 .--(continued)

Species		Location: Philadelphia Flat 6/2	Philadelphia Flat 7/10	Philadelphia Flat 9/12	Summit Enclosure 5/31	Summit Enclosure 7/6	Summit Enclosure 9/11
Orthocarpus tolmiei	Emergence	0.0	0.0	0.0	0.0	0.3	0.3
	Mortality		0.0	0.0		0.3	0.3
Osmorhiza occidentalis	Emergence	31.0	68.0	68.0	—	—	—
	Mortality		30.0	33.0		—	—
Penstemon rydbergii	Emergence	0.0	8.7	8.7	8.3	29.3	29.3
	Mortality		7.7	8.0		29.3	29.3
Polygonum douglasii	Emergence	9.3	30.0	30.0	18.7	34.7	34.7
	Mortality		5.3	9.0		22.7	23.7
Polemonium foliosissimum	Emergence	1.5	11.5	11.5	—	—	—
	Mortality		9.0	9.5		—	—
Potentilla glandulosa	Emergence	0.0	0.0	0.0	0.0	8.3	8.3
	Mortality		0.0	0.0		8.3	8.3
Potentilla pulcherrima	Emergence	0.0	0.0	0.0	0.3	1.7	1.7
	Mortality		0.0	0.0		1.7	1.7
Pseudocymopterus montanus	Emergence	0.0	0.0	0.0	0.0	5.3	5.3
	Mortality		0.0	0.0		3.0	4.0
Ribes inebrians	Emergence	0.0	2.0	2.0	—	—	—
	Mortality		2.0	2.0		—	—
Ribes montigenum	Emergence	0.0	1.0	1.0	0.0	17.7	17.7
	Mortality		1.0	1.0		17.7	17.7
Rudbeckia occidentalis	Emergence	0.0	0.0	0.0	0.0	34.7	34.7
	Mortality		0.0	0.0		34.0	34.3
Rumex mexicanas	Emergence	0.0	0.0	0.0	—	—	—
	Mortality		0.0	0.0		—	—

Table 7 .--(continued)

Species		Location: Philadelphia Flat 6/2	Philadelphia Flat 7/10	Philadelphia Flat 9/12	Summit Enclosure 5/31	Summit Enclosure 7/6	Summit Enclosure 9/11
Sambucus racemosa	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Stellaria jamesiana	Emergence	3.0	13.0	13.0	—	—	—
	Mortality		13.0	13.0		—	—
Taraxacum officinale	Emergence	0.0	0.0	0.0	—	—	—
	Mortality		0.0	0.0		—	—
Valeriana edulis	Emergence	0.0	1.7	1.7	0.0	44.0	44.0
	Mortality		1.7	1.7		42.3	42.7
Viguiera multiflora	Emergence	0.0	8.7	8.7	6.0	14.3	14.3
	Mortality		6.0	6.0		7.0	8.0
Viola nuttallii linquaefolia	Emergence	0.0	58.3	58.3	0.0	37.0	37.0
	Mortality		22.3	31.3		7.0	11.3
Zigadenus elegans	Emergence	0.7	4.7	4.7	0.0	7.0	7.0
	Mortality		4.7	4.7		7.0	7.0

in the unfrozen soil under the deep snow. Typical of these plants were mountain brome, slender wheatgrass, native Stipa, and tarweed. Seeds of another group did not germinate in the fall or winter while the soil was cool, but germinated after the soil warmed up in the spring, or germinated readily at 68 to 82° F. in the laboratory. Typical of this latter group were Aquilegia and Potentilla.

III-E. Seed germination and responses in snow, sand, and soil.

Additional studies were established at the Headquarters Station in the fall of 1960 to provide information on factors which may limit or curtail germination, emergence and establishment of plants on areas normally covered by deep snow during the winter season. Special emphasis was placed on seed germination in relation to temperatures in the snow, at the soil surface, below the soil surface, and 4 inches below the soil surface.

Seeds of four species, all harvested in 1960, were used in this study. Species used were: intermediate wheatgrass grown on the Frischknect farm in Sanpete County, progeny of P-2327; a field collection of smooth brome grown in Ephraim Canyon at 8,850 feet; native slender wheatgrass from an elevation of 10,000 feet in Ephraim Canyon. Seeds of all species were harvested by hand and thoroughly cleaned. Seed was separated into units with 100 seeds of a single species per unit. Each unit was placed in a small nylon mesh bag and the bags were closed and stitched to prevent seed loss.

The study area was prepared during the late summer and fall of 1960. Two areas approximately 15 feet apart were cleared and staked so that sacks could be located after deep snow covered the site.

Five "planting" treatments were used in this study. These included placing sacks under 3/4-inch of native soil, placing sacks under 4 inches of native soil, placing seed on the soil surface under snow, planting under 3/4-inch of sand on a sand mound, and suspending sacks in the snow approximately 4 inches above the soil surface. Sand mounds were made by building a frame 3 feet square and 5 inches high with galvanized

wire screen supported by lath stakes at all corners and at intervals along the sides. This frame was filled with builders sand. Wooden frames 2 feet square and 6 inches high were made to support the sacks in the snow. Ends of the frames were solid but the sides were partly open to allow lateral movement of snow. Four nylon cords were stretched across the top of the frame and the sacks were stitched to the nylon cords.

Plantings were made on November 15, 1960 under 8 inches of snow. The upper 1/4 inch of sand was frozen and an ice layer was found just above the soil but the soil surface was thawed. Plantings in the soil were made in 3/4 and 4-inch pits dug prior to snow fall. Bags placed in these pits were covered with the soil that had been removed when the pits were made. Similar planting procedures were used for planting in the sand mounds under 3/4 inch of sand. Frames with bags in place were placed on the native soil with the bottoms of the bags suspended in the air about 4 inches above the soil surface. Bags placed on the soil surface were set in place and covered with snow to hold them in place. When all plantings were complete, a snow cover 10 inches deep was placed over the plot.

Snow depth increased to 20 inches by the end of November but varied between 14 inches and 25 inches during December and January. The soil surface was frozen intermittently from the planting date until late December when deep freezing occurred. Soil at a depth of 3/4 inch was moist and thawed until late December and soil at the 6 inch depth was frozen by late January due to the relatively shallow snow cover. Snow depth increased to 37 inches in late February and

reached a maximum depth of 54 inches on April 10, 1960.

The soil surface started to thaw in the middle of March and intermittent light freezing and thawing continued until snowmelt on May 22. The 3/4-inch depth began to thaw in early April and the soil remained thawed and moist from late April to snowmelt. Soil at the 4-inch depth was thawed from the first of April to snowmelt.

The first seed lots were removed on April 1 when the snow depth was 51 inches deep. The soil surface was partly frozen. Some seeds of intermediate wheatgrass and smooth brome had started to germinate at all locations. As shown in Table 8 the native slender wheatgrass and native mountain brome had not started to germinate in the snow but had germinated at the other locations.

The second sample was removed on April 15 when the snow depth was still 18 inches deep. The soil was moist with many earthworms observed at 1/2 to 1 inch below the soil surface. Seeds in the snow and at 3/4 and 4-inch depths were frequently infected with fungi. Germination of intermediate wheatgrass seed was relatively high at all locations and some seed of all species had germinated at all locations except the slender wheatgrass seed in the snow. Table shows that seed dormancy in the native mountain brome had not been fully broken in the sand, at the soil surface, and in the snow. Total seed germination in native slender wheatgrass was higher than comparable germination in mountain brome but some seed dormancy was also observed.

Table 8 . Percent germination in seeds of four grasses placed in snow, under 3/4 inch sand, on soil surface, under 3/4 inch soil, and under 4 inches of soil, after permenent winter snow was on the ground when removed on two dates just as the snow thawed (4/1) and just before spring snowmelt (5/15).

Sampling Date		Planting Location				
		Sand	Snow	Surface	3/4 inch Soil	4 inch Soil
				Percent		
	Intermediate wheatgrass					
4/1/61	On removal	32.7	6.0	52.7	82.7	65.0
	Complete	93.3	94.3	95.0	93.0	88.7
5/15/61	On removal	81.3	37.7	84.3	77.0	94.7
	Complete	94.7	96.7	96.3	79.0	95.0
	Slender wheatgrass					
4/1/61	On removal	23.3	0.0	4.7	61.3	38.7
	Complete	74.3	59.3	82.7	91.0	90.7
5/15/61	On removal	32.7	0.0	10.3	87.3	90.7
	Complete	88.3	63.3	80.7	93.3	97.7
	Mountain brome					
4/1	[illegible]moval	9.0	0.0	1.3	88.3	86.3
	Complete	15.7	1.3	3.7	89.0	87.0
5/15/61	On removal	17.3	0.7	4.0	87.0	90.7
	Complete	18.7	1.3	4.7	88.0	90.7
	Smooth brome					
4/1/61	On removal	3.3	1.7	17.0	21.0	9.3
	Complete	76.3	74.7	75.7	77.7	65.7
5/15/61	On removal	16.7	23.0	23.7	29.3	26.0
	Complete	73.7	76.7	65.7	62.3	60.7

IV-A. Decomposition of organic matter during the winter at high elevations.

Decomposition of organic material under a deep snow has been observed since 1956. Disintegration appears to be primarily due to the action of fungi and perhaps bacteria, but no attempt has been made to study the flora or fauna. Decomposition of organic matter can directly or indirectly influence seed germination and plant growth by modifying the environment.

Plants of smooth brome, slender wheatgrass, tall bluebell, and mountain lupine were harvested in the hay stage in 1960. Decomposition in the winter of 1959-1960 was included in the 1960 report. These species were selected to obtain coarse and relatively fine stemed grasses and forbs.

The air dried material was divided into samples containing 25 grams. Three units of each species were placed in fine mesh nylon bags and the bag openings were sewn. Six units of each species were placed in aluminum foil envelopes. One half of the units in the aluminum foil were placed in an oven at 80° C for 24 hours to obtain oven-dry weights for all samples. Thus samples used for decomposition measurements were not subjected to high temperatures.

All samples in aluminum foil were placed under a tin shed in the fall of 1960. Openings in the envelopes were arranged to allow free air movement but still protect the samples from falling moisture and dust.

Samples in nylon bags were placed on bare soil within the enclosure on Philadelphia Flat on October 7. Intermittant shallow snow covered the bags until a heavy snow fell on November 4. Air temperatures

had been low and the soil was frozen to a depth of about 1 inch before the November 4 storm. Snow depth was 19 inches on November 30 and nearly 6 feet in late March. Bags were removed from the soil on May 30, 1960 just as the snow melted in the spring exposing the nylon bags (figure13).

Soil and litter on the outside of the nylon bags were removed by gentle brushing but no attempt was made to remove soil that had filtered into the bags. All bags from the field and all bags from the shed were uniformly dried in the laboratory for 3 weeks. Air-dry weights were taken on all samples and oven dry weights were then determined on the units in the aluminum envelopes.

All air-dry weights were changed to oven-dry weights based on these determinations. The change in oven-dry weights, on the check samples stored in the shed during the winter, ranged from -0.43 to +0.60 percent.

Table 9 shows the plant material lost from the nylon bags during the winter ranged from an average of 54.6 percent for lupine to 25.1 percent for the coarse stemmed slender wheatgrass. Actual weight loss is estimated to be from 5 to 10 percent greater than shown due to the infiltration of soil into these bags. Quantitative assays will be made as soon as time permits.

Percent Decomposition for the respective coarse leafed and fine leafed plants was similar to results in 1959-1960. In both years the soil cooled in the fall and the soil surface was frozen before a deep protective snow blanket covered the area. Other observations and measurements have shown a much higher percent Decomposition when a heavy permanent winter snow covered the area while the soil was

Figure 13 . Nylon bags containing plant material were placed on the soil surface on October 7 and removed on May 30, 1961, just as the winter snow melted. (ATB-61-37)

Table 9 . Decomposition of plant material of four species on the soil surface under snow in the winter of 1960-1961.

Species	Sample	Percent comoosition Leaves	Stems	Oven dry 1/ Wt. in grams 1960	1961	Change in Wt. Decomposition Grams	Percent
Mertensia leonardi	1	48	52	23.44	11.06	12.38	52.82
	2	48	52	23.44	12.01	11.43	48.76
	3	48	52	23.44	11.45	11.99	51.15
	Avg.	48	52	23.44	11.51	11.93	50.91
Lupinus alpestris	1	59	41	23.18	10.34	12.84	55.39
	2	59	41	23.18	11.54	11.64	50.22
	3	59	41	23.18	9.69	13.49	58.20
	Avg.	59	41	23.18	10.52	12.66	54.60
Agropyron trachycaulum	1	26	74	23.31	17.76	5.55	23.81
	2	26	74	23.31	16.84	6.47	27.76
	3	26	74	23.31	17.78	5.53	23.72
	Avg.	26	74	23.31	17.46	5.85	25.10
Bromus inermis	1	54	46	21.63	14.36	7.27	33.61
	2	54	46	21.63	13.36	8.27	38.23
	3	54	46	21.63	13.25	8.38	38.74
	Avg.	54	46	21.63	13.66	7.97	36.86

1/ Samples contain small amounts of soil but quantitative measurements have not been made at this time.

relatively warm. For example, in August 1958, herbage production within a stock exclosure averaged 1,200 pounds dry weight per acre. By snow-melt, on June 3, 1959, only 110 pounds of total litter per acre could be collected.

IV-B. Pocket gophers on rangelands.

High gopher populations have been observed on many depleted high elevation sites. Pocket gophers were trapped in the fall of 1957, 1958, 1959, 1960, and 1961 on and near several revegetation study areas at approximately 10,000 feet in central Utah. Records of total animals caught have been kept on a 4-acre area located on Philadelphia Flat for the years 1958, 1959, 1960, and 1961. In 1958, a total of 63 animals or 15.8 gophers per acre were trapped. In 1959, 102 animals (46 adults and 56 young gophers) or 25.5 gophers per acre were trapped. In 1960, 42 animals (17 adults and 25 young) or 10.5 gophers per acre were caught. In 1961, 48 gophers (6 adults and 42 young) or 12.0 animals per acre were trapped.

Although there was evidence that at least 4 animals had been working on this 4-acre area during the period the area was covered with winter snow, no animals were caught on this area from snowmelt, about May 31, to July 25, 1961, when two adults were trapped. As shown below, only five young and the two adults were trapped during the period May 31 to August 23.

Gophers trapped in 1961

Date	Adult	Young
7-25-61	2	-
8-3-61	-	1
8-7-61	-	2
8-10-61	-	2
8-24-61	-	10
8-28-61	-	5
9-1-61	-	3
9-5-61	-	1
9-6-61	1	6
9-7-61	2	6
9-8-61	-	2
9-11-61	-	2
9-12-61	1	2
Total	6	42

In general, very few recent pocket gopher workings were observed on study areas at high elevations during the spring or summer of 1961. This was also true for most of the spruce-fir zone in central Utah. Apparently the gopher population was reduced by the light flooding that occurred on low and near level terraces in the fall of 1960 followed by freezing of the soil under the snow. Frozen soil existed from late fall of 1960 until late March of 1961. The soil was frozen due to a relatively thin snow cover and low air temperatures that prevailed in December, January, and February.

A sharp increase in gopher mounds was observed in late summer and early fall after the soil was moistened by storms. Most of the gophers trapped during this period at the various study areas were small, young animals.

Gopher activity in the snow above the soil surface increased markedly after the February-March period in 1957, 1958, and 1959, and continued until snowmelt in the spring. Much of the surface soil was frozen at high elevations in 1960 and 1961 and accelerated gopher activity in the snow was not observed until March. The increased activity in the February-March period appears to be related to thawing of the soil when it has been frozen, an increase in temperatures of the surface soil and snow near the soil surface, a depletion of stored food reserves, additional food supply available by elongation of grasses and forbs and a need for storage space for soil and waste material.

A large number of nests have been observed. Most of these have been at least 6 inches above the soil surface but in the spring of 1959 and 1960 several nests were found just above the soil surface

or in shallow excavations below the soil surface. In 1961, all nests observed were near the soil surface. Nests found in the snow have usually been lined with dried grass or shredded bark. A number of soil filled nests have also been found. These nests were made with grass on the bottoms and sides but nests and tunnels leading to the nests were later filled with soil or waste material.

Most of the burrows and soil casts observed in the snow were within 3 inches of the soil surface but one cast, 27 inches above the soil surface, was found in the spring of 1958. Gopher damage was rather severe on the study areas on Philadelphia Flat in the spring of 1957, 1958, and 1959 but little damage was observed in the spring of 1960 or 1961. Where casts were placed in the snow or near the soil surface, the casts often followed depressions in the soil, such as furrows. On furrowed plots where gophers were active, from 11 to 37 percent of the drill rows in the bottom of the furrows were covered with soil casts. These casts were usually 1 1/2 to 2 1/2 inches in diameter; thus seeds and seedlings were often covered with 2 to 3 inches of soil when casts were placed in the bottom of the furrows directly over the seed. Number of seedlings were decreased from 35 to 90 percent where soil casts covered the seed row. Some damage to established plants has been observed when casts covered the crowns but mortality of these plants has been low.

Pocket gophers apparently eat a wide variety of plants. Food caches observed in the spruce-fir zone frequently contained roots of dandelion, tubers of starwort, corms of springbeauty, and bulbs of troutlily, although some caches have been predominantly or exclusively one species. Most of the food caches found have been in the snow at least 6 inches

above the soil surface. In the spring of 1960 a cache was found in a burrow below the soil surface. In the spring of 1961 only two small food caches were found in the spruce-fir zone.

Established grasses, forbs, and shrubs have been damaged or killed when the root system or crowns have been disturbed by burrowing gophers. Damage has occured both in summer and winter and at relatively low and high elevations. Stands of established crested wheatgrass, Indian ricegrass, and other grasses were severely damaged on a shadscale type near Gunnison, Utah. Primary damage was effected by burrowing beneath the plants and either eating or cutting the root systems. Damage to many other plants including shadscale and fourwing saltbush also occurred on this site. Shrubs were killed by severing the roots. Apparently the roots were used as food.

Field observations have shown that pocket gophers show a preference for some plants for food. In plant nurseries located at various elevations in Ephraim Canyon, gopher workings will often be concentrated within areas where preferred plants are growing. At a mountainbrush site a concentration of mounds and soil casts were found within an area planted to alfalfa while very few mounds were located in the surrounding grass plots. In the grass nurseries the gophers showed preference for orchardgrass, tall oatgrass, timothy, bulbous barley, and quackgrass. Observations made in 1958, 1959, 1960, and 1961, indicated that considerable utilization of grasses and forbs took place above the soil surface during the winter or spring when the area was covered with snow. Gophers showed a marked preference for orchardgrass. Winter cores on many orchardgrass and other grass plots frequently consisted of dead stems

and leaves and waste material that had been removed from the area around the living plants to enable the gophers to reach the green leaves and living crowns. Observations made in the fall prior to snow fall, in the spring after snowmelt, and in the summer have shown that orchard-grass areas utilized under the snow by gophers are also utilized by rabbits during the spring and summer.

Pocket gopher activities have been followed and studied in conjunction with other work because of the damage these animals have done to seeded stands, revegetation studies and especially to the seed germination studies conducted under snow. These animals have been numerous on most harsh sites at high elevations in Utah where the vegetation has been depleted. Gophers directly damaged planted and native grasses and forbs by eating or destroying leaves, crowns, roots, or indirectly damaged these plants by covering seeds, seedlings, or established plants with winter soil casts or summer soil mounds.

IV-C. Uniform study for seeding depleted sites on western ranges.

Plans to establish a uniform study were first made at the Range Society Meetings held at Great Falls in January 1957. This study was conducted at six locations, as follows: Bozeman, Montana; Ephraim, Utah; La Grande, Oregon; Logan, Utah; Pullman, Washington; and Reno, Nevada. A general plan of study was made from the composite suggestions by Dr. Keller and the field men located at the above areas. A.C. Hull acted as coordinator, and assembled this material into study plan form.

The first plantings were made on one area at each location according to plan in the fall of 1957, and spring of 1958. Subsequent plantings at this site were made in the fall of 1958, spring and fall of 1959, and in the fall of 1960. Additional spring plantings will be made after the snow melts in 1961. This report will include the fourth year results from the 1957-1958 plantings, the third year results from the 1958-1959 plantings, the second year results from the 1959-1960 plantings, and the first year results from the 1960-1961 plantings. Progress reports for 1958 and 1959 contain data for the 1957-1958, 1958-1959, and 1959-1960 periods respectively.

Major treatments included nine seedbed treatments applied on the contour and five fertilizer treatments applied up and down the slope at right angles to seedbed treatments. Seedbed treatments and fertilizer treatments applied or to be applied in each of the four years are listed below.

A. Seedbed treatments	1st Year 1957-1958	2nd Year 1958-1959	3rd Year 1959-1960	4th Year 1960-1961
1. Plow fall - summer fallow plant next fall	x	x	x	

		1st Year 1957-1958	2nd Year 1958-1959	3rd Year 1959-1960	4th Year 1960-1961
2.	Plow fall - preparatory crop in fall - plant next fall	x	x	x	
3.	Plow fall - plant in fall	x	x	x	x
4.	Valley soil - plant in fall	x	x	x	x
5.	Plow fall - plant in fall - ½" sawdust	x	x	x	x
6.	Plow fall - transplants	x	x	x	x
7.	Plow fall - 4" contour furrows - plant in fall	x	x	x	x
8.	Plow fall - plant spring	x	x	x	x
9.	Check - no seedbed preparation or treatment	x	x	x	x
10.	Plant fall - spray 4 lbs. 2,4-D in spring	x	x	x	
11.	Spray 4 lbs. 2,4-D in spring - plant in fall	x	x	x	
12.	Spray 4 lbs. 2,4-D in spring - plant spring			x	
13.	Plow fall - plant fall and cover seed with sand			x	x
B.	Fertilizer treatment				
1.	Nitrogen - 100# per acre N	x	x	x	
2.	Phosphorus - 200# per acre P_2O_5	x	x	x	
3.	Nitrogen plus phosphorus	x	x	x	
4.	Nitrogen, phosphorus, potash plus minor elements	x	x	x	x
5.	Check	x	x	x	x

Plantings were made on Forest Service land within two enclosures constructed by the Forest Service for this study. The two areas are

only about two miles apart, but slope and exposure are quite different:

(1) Philadelphia Flat - is located on a wide near level terrace at an elevation of approximately 10,000 feet. This area is frequently snow covered from the first heavy snow in October or November until the air temperature is relatively high the following May or early June when frost danger is low. When dry or unfrozen soil is covered by snow in the fall, the soil may remain at or above freezing throughout the winter. This area is subjected to flooding during rapid snowmelt in the spring. Flooding may also cause a breakdown in the soil structure which in turn may decrease soil aeration, reduce water holding capacity, and favor crusting.

(2) Summit Enclosure - is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth during the winter period on this area is usually less than on Philadelphia Flat due to increased melting in the fall and spring and wind action. Soil may be frozen during the winter. When the soil is bare or snow covering is shallow, alternate freezing and thawing may produce heaving, frost damage, or rapid drying of the surface soil around the seeds. Flooding has been observed but does not appear to be a serious problem on this site.

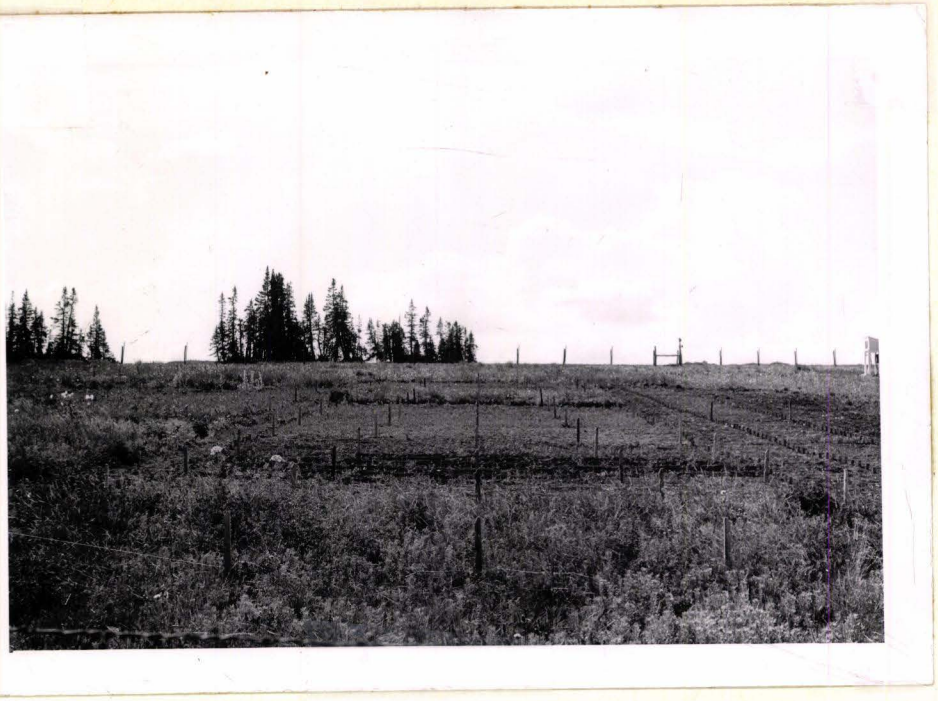
Fertilizers did not appear to improve stand establishment or increase herbage production at either site. Native slender wheatgrass and mountain brome have consistently produced better seedling stands than the domestic grasses but these species are relatively short-lived. Fair to good stands of smooth brome, intermediate wheatgrass, pubescent wheatgrass, and artic Agropyron have been obtained. On old nearby studies smooth brome and similar long-lived grasses that spread vegetatively have been superior.

This study has demonstrated that success or failure of a seeding may be determined by one condition on one site and another condition on an adjacent area. In general, treatments that remove the native condition and provide some protection for adapted species have been satisfactory. Treatments that have been consistently best at Philadelphia Flat are valley soil, sawdust mulch, and contour furrows.

The treatment that has been consistently best at Summit Enclosure is sawdust mulch and the spring drilling has been next best. Plant numbers were low on other treatments at the Summit Enclosure.

Percent soil moisture has been determined at intervals throughout the growing season at both study areas. Soil and air temperatures during the growing season have been recorded with a 7-day recording thermometer at the Summit Enclosure (figure 14). Figure 15 shows the 31-day recording thermometer at Philadelphia Flat that remained in operation throughout the year. At both locations, standard air temperatures and soil temperatures at 3/4 inch depths were recorded. At the Summit area, additional temperatures were recorded at 6 inches above the soil surface and 1/4 inch below the soil surface. At Philadelphia Flat an additional temperature unit was located on the soil surface during the period that winter snow covered the area. This unit was placed in the soil at 1/4 inch depth during the spring, summer, and fall.

Plot areas for the 1960-1961 studies were plowed during the first week in September. Fall plantings were made and a complete fertilizer was applied on two replications at each site on September 26 and 27. Transplants of Calamagrostis epigeios, reed canarygrass, Kentucky



Figures 14 and 15. Soil moisture, air temperatures and soil temperatures were recorded during the growing season (61-60). The 31-day recording thermometer shown in the lower photo was operated throughout the year (61-135)

bluegrass, smooth brome, intermediate wheatgrass, and pubescent wheatgrass were made on October 31. Spring plantings were made on June 9, 1961. Species used in these plantings differed from previous years in that intermediate wheatgrass and Bromus tomentellus were used instead of tall oatgrass and red fescue.

Snow fell at high elevations in early October but it was largely gone by October 31. Low temperatures in late October caused severe frost action and the surface soil was frozen. Additional snow fell in early November and subsequent storms in late November and early December maintained a snow cover from 16 to 22 inches deep. Clear skies, low temperatures and relatively shallow snow depths during the latter part of December and January resulted in a general freezing of the soil to depths of 3 to 6 inches. Snow depth at Philadelphia Flat increased to 64 inches in March and remained over 4 feet deep until the middle of May. Snow on the Summit plot melted on May 22 and snow on Philadelphia Flat melted during the period May 28 to June 1, 1961.

The soil surface thawed prior to snowmelt but cold temperatures during the spring period caused relatively slow snowmelt. Soil flooding during the spring snowmelt period was less than in any year since the first records were made in the spring of 1956. Light frosts occurred at night immediately following spring snowmelt but frost damage was low. Very little soil crusting was observed in the spring of 1961 and seedling emergence was relatively high.

Seedling counts were made on July 11 or 12 and August 24 on both Philadelphia Flat and the Summit Enclosure (Tables 10 and 11). The number of plants per foot of row during the second growing season on

Table 10. Number of plants per foot of row on eight treatments on two dates during the 1961 seeding year at Philadelphia Flat.

	Fall of 1960							Spring 1961	
	Drill fall	Contour furrows	Sawdust	Cover seeds with sand	Summer fallow1/	Preparatory crop 1/	Spray s. Seed Drill f1/	Spring	Average
	July 12, 1961								
Intermediate wheatgrass	1.34	1.64	1.81	1.35	0.59	0.40	0.37	0.66	1.02
Slender wheatgrass	2.35	2.64	2.78	1.90	1.28	0.80	0.55	0.31	1.58
Mountain brome	3.72	2.83	2.87	2.52	2.02	1.92	1.52	0.70	2.26
Smooth brome	0.79	1.16	1.15	0.87	0.29	0.00	0.29	0.81	0.67
Bromus tomentelis	1.23	1.73	1.06	1.64	0.38	0.20	0.26	0.21	0.84
Average	1.89	2.00	1.93	1.66	0.91	0.66	0.60	0.54	1.27
	August 24, 1961								
Intermediate wheatgrass	1.38	1.38	1.71	1.21	0.57	0.60	0.40	0.95	1.02
Slender wheatgrass	1.49	1.80	2.35	1.44	0.99	0.54	0.60	1.30	1.31
Mountain brome	2.95	3.19	3.35	2.45	2.09	1.64	1.43	2.05	2.39
Smooth brome	0.79	1.26	1.16	0.86	0.37	0.08	0.47	0.97	0.74
Bromus tomentelis	1.25	1.72	1.41	1.34	0.40	0.35	0.38	0.90	0.97
Average	1.57	1.87	2.00	1.46	0.88	0.64	0.66	1.23	1.29

1/ Average at site 4 and site 5.

Table 11. Number of plants per foot of row on eight treatments on two dates during the 1961 seedling year at Summit Enclosure.

	Fall of 1960							Spring 1961	
	Drill fall	Contour furrows	Sawdust	Cover seed with sand	Summer fallow 1/	Straw mulch 1/	Spray s. f. Drill 1/	Seed Spring	Average
	July 17, 1961								
Intermediate wheatgrass	2.23	2.50	0.96	0.90	1.07	1.04	0.42	0.65	1.22
Slender wheatgrass	1.52	2.27	1.35	1.28	1.15	1.33	0.54	0.44	1.24
Mountain brome	2.50	2.61	1.65	2.02	1.26	0.73	0.39	0.44	1.45
Smooth brome	1.16	1.30	0.56	1.02	0.54	0.68	0.16	0.15	0.70
Bromus tomentelis	1.99	1.62	0.81	1.15	0.73	0.66	0.32	0.22	0.94
Average	1.88	2.06	1.07	1.27	0.95	0.89	0.37	0.38	1.11
	August 24, 1961								
Intermediate wheatgrass	2.00	2.52	1.26	1.28	0.98	1.35	0.56	0.95	1.36
Slender wheatgrass	1.61	2.00	1.78	1.30	1.01	1.13	0.48	0.82	1.27
Mountain brome	2.52	2.26	1.74	1.86	0.97	0.55	0.41	1.16	1.43
Smooth brome	1.50	1.33	0.95	1.10	0.59	0.69	0.36	1.15	0.96
Bromus tomentelis	1.72	1.76	1.16	1.12	0.81	0.53	0.40	1.34	1.10
Average	1.87	1.97	1.38	1.33	0.87	0.85	0.44	1.08	1.22

1/ Average for site 4 and site 5.

plots planted in the fall of 1959 and the spring of 1960 are shown in Table 12. Number of plants per foot of row during the third and fourth growing season are shown in Tables 13 and 14. Number of plants for three consecutive years at Summit and Philadelphia Flat on the plots drilled in the fall are shown on Tables 15 and 16. Yield per acre for planted and native species in the second, third and fourth growing season are shown in Tables 17 to 19.

Table 12. Average number of plants per foot of row on 12 treatments during the second growing season at Philadelphia Flat and Summit Enclosure.

Species	Fall of 1959								1/	1/	1/	Spring 1960	
	Drill-f spray -s	Spray-s drill-s	Drill	Valley Soil	Contour furrows	Sawdust +N	Sawdust	Cover seed with sand	Spray drill	Summer fallow	Straw mulch	Drill	Average
						Phil. Flat - Aug 24, 1961							
Slender wheatgrass	0.98	0.65	2.04	8.50	1.66	1.33	2.10	2.60	0.78	1.72	0.66	0.79	1.98
Tall oatgrass	0.11	0.08	0.34	3.50	0.01	0.01	0.05	0.20	0.04	0.11	0.02	0.04	0.38
Mountain brome	0.95	0.58	2.09	4.75	1.19	1.33	1.45	2.08	0.97	1.97	0.80	1.17	1.61
Smooth brome	0.24	0.25	0.84	5.27	0.54	0.33	0.45	0.59	0.14	0.35	0.03	0.53	0.80
Red fescue	0.06	0.00	0.57	6.75	0.28	0.46	0.40	0.62	0.17	0.39	0.00	0.00	0.81
Average	0.47	0.31	1.18	5.75	0.76	0.69	0.89	1.22	0.42	0.91	0.30	0.51	1.12
						Summit - Aug. 24, 1961							
Slender wheatgrass	0.24	0.12	1.79	4.50	1.28	1.56	1.10	5.01	0.55	1.43	0.47	0.70	1.56
Tall oatgrass	0.02	0.00	0.14	2.00	0.10	0.05	0.60	0.08	0.00	0.02	0.00	0.21	0.27
Mountain brome	0.08	0.17	0.97	2.00	0.67	0.62	0.20	1.67	0.11	0.26	0.18	1.23	0.68
Smooth brome	0.10	0.08	0.83	5.75	0.80	0.55	0.30	1.93	0.39	0.66	0.12	0.36	0.99
Red fescue	0.00	0.00	0.83	4.00	0.44	0.32	1.00	0.79	0.00	0.32	0.00	0.06	0.65
Average	0.08	0.07	0.91	3.65	0.66	0.62	0.64	1.90	0.21	0.54	0.15	0.51	0.83

1/ Average of site 2 and site 3.

Table 13. Number of plants per foot of row on nine treatments during the third growing season at Philadelphia Flat and Summit Enclosure.

	Fall 1958								Spring 1959	
	Drill spray	Drill	Contour furrows	Sawdust +N	Sawdust	Spray drill	Summer fallow	Straw mulch	Drill	Average
	Philadelphia Flat August 24, 1961									
Slender wheatgrass	0.64	2.68	2.50	2.42	3.80	0.48	2.82	1.80	1.11	2.03
Tall oatgrass	0.01	0.02	0.05	0.13	0.70	0.00	0.60	0.00	0.07	0.18
Mountain brome	0.69	2.24	2.38	2.30	2.10	0.84	2.24	2.34	1.29	1.82
Smooth brome	0.04	1.31	1.14	1.55	2.30	0.04	1.02	0.40	0.55	0.93
Red fescue	0.03	0.05	0.08	0.50	1.10	0.00	0.80	0.04	0.01	0.29
Average	0.28	1.26	1.23	1.38	2.00	0.27	1.50	0.92	0.61	1.05
	Summit Enclosure August 24, 1961									
Slender wheatgrass	0.20	0.96	0.87	1.20	1.65	0.08	0.36	0.22	0.51	0.67
Tall oatgrass	0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.01
Mountain brome	0.07	0.11	0.23	0.12	0.15	0.06	0.10	0.08	0.06	0.11
Smooth brome	0.08	0.71	0.27	0.66	1.20	0.04	0.10	0.12	0.93	0.46
Red fescue	0.01	0.00	0.02	0.00	0.00	0.00	0.02	0.06	0.02	0.01
Average	0.07	0.36	0.28	0.40	0.60	0.04	0.12	0.10	0.30	0.25

Table 14. Number of plants per foot of row on seven treatments during the fourth growing season on Philadelphia Flat and Summit Enclosure.

	Planted Fall 1957						Spring 1958	
	Drill spray	Drill	Valley soil	Contour furrows	Sawdust +N	Sawdust	Drill	Average
	Philadelphia Flat August 24, 1961							
Slender wheatgrass	0.36	1.46	4.50	1.48	2.00	2.70	0.90	1.91
Tall oatgrass	0.00	0.00	0.50	0.00	0.00	0.00	0.14	0.09
Mountain brome	0.28	0.86	3.20	2.10	1.72	2.30	0.88	1.62
Smooth brome	0.02	0.00	1.50	0.00	0.02	0.00	0.22	0.25
Red fescue	0.00	0.00	1.00	0.00	0.00	0.00	0.02	0.15
Average	0.13	0.46	2.14	0.72	0.75	1.00	0.43	0.80
	Summit Enclosure August 24, 1961							
Slender wheatgrass	0.12	0.08	0.00	0.42	1.90	2.40	0.30	0.75
Tall oatgrass	0.00	0.00	0.00	0.06	0.02	0.20	0.02	0.04
Mountain brome	0.12	0.04	0.00	0.08	0.14	0.02	0.04	0.06
Smooth brome	0.00	0.00	0.00	0.06	0.24	0.40	1.04	0.25
Red fescue	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.03
Average	0.05	0.02	0.00	0.12	0.48	0.62	0.28	0.23

Table 15. Number of plants per foot of row by species and by fertility treatment on the drill fall plots at Philadelphia Flat and Summit Enclosure for three consecutive plantings (1957-1960).

	Philadelphia Flat				Summit Enclosure			
Species	2nd growing season	3rd growing season	4th growing season	Average	2nd growing season	3rd growing season	4th growing season	Average
Slender-wheatgrass	2.04	2.68	1.46	2.06	1.79	0.96	0.08	0.94
Tall oatgrass	0.36	0.02	0.00	0.13	0.14	0.02	0.00	0.05
Mountain brome	2.09	2.19	0.86	1.71	0.97	0.11	0.04	0.37
Smooth brome	0.84	1.31	0.00	0.72	0.83	0.71	0.00	0.51
Red fescue	0.57	0.05	0.00	0.21	0.83	0.00	0.00	0.28
Average	1.18	1.25	0.46	0.97	0.91	0.36	0.02	0.43
Fertilizers								
Check-none	1.09	1.22	0.64	0.98	1.05	0.29	0.02	0.45
Nitrogen	1.11	1.25	0.36	0.91	0.88	0.42	0.02	0.44
Phosphorus	1.28	1.32	0.40	1.00	1.02	0.38	0.02	0.47
N + P	1.25	1.22	0.32	0.93	0.82	0.40	0.02	0.41
Complete	1.17	1.24	0.60	1.00	0.79	0.31	0.04	0.38
Average	1.18	1.25	0.46	0.97	0.91	0.36	0.02	0.43

Table 16 . Number of plants per foot of row by species and by fertility treatment on the Buffer Plot at Philadelphia Flat and Summit Enclosure for three consecutive fall plantings (1957-1960).

Species	Philadelphia Flat				Summit Enclosure			
	2nd growing season	3rd growing season	4th growing season	Average	2nd growing season	3rd growing season	4th growing season	Average
Intermediate wheatgrass	0.80	1.14	0.00	0.65	1.24	0.55	0.28	0.69
Agropyron spp.	1.33	1.25	-	1.29	1.60	1.98	-	1.79
Stiffhair wheatgrass	0.71	0.64	0.12	0.49	0.87	0.16	0.12	0.38
Meadow foxtail	0.13	0.05	0.00	0.06	0.42	0.07	0.00	0.16
Orchardgrass	0.71	1.13	0.00	0.61	0.54	0.00	0.00	0.18
Average	0.74	0.84	0.03	0.57	0.93	0.55	0.10	0.56
Fertilizers								
Check-none	0.78	0.67	0.06	0.50	1.06	0.48	0.18	0.57
Nitrogen	0.61	0.80	0.00	0.47	0.98	0.53	0.06	0.52
Phosphorus	0.79	0.78	0.02	0.53	1.11	0.73	0.00	0.61
N+P	0.77	0.68	0.02	0.49	0.81	0.54	0.10	0.48
Complete	0.73	0.78	0.02	0.51	0.71	0.48	0.06	0.42
Average	0.74	0.74	0.02	0.50	0.93	0.55	0.08	0.52

Table 17. Average oven dry yield in pounds per acre for planted species during the second growing season and existing native species on the check plots at Philadelphia Flat and Summit Enclosure.

	Fall - 1959											Spring 1960		F-1959	
	Drill-F spray-S	Spray-S drill-S	Drill	Contour furrows	Sawdust +N	Sawdust	Cover sand	Spray drill	Summer fallow	Prep. crop	Trans-plant	Drill	Check	Buffer Species 1/	Yield
Philadelphia Flats - September 6, 1961															
Slender wheatgrass	375	200	707	707	671	537	601	246	475	436	-	136	-	Agin^2	344
Tall oatgrass	5	0	200	0	20	20	110	0	40	0	-	15	-	Agsp	448
Mountain brome	475	250	778	607	453	362	545	211	650	192	-	253	-	Agtr^2	220
Smooth brome	40	25	462	323	194	155	346	194	85	84	1077	168	-	Alpr	20
Red fescue	15	0	100	15	130	104	120	5	85	0	-	0	-	Dagl	352
Native species	1259	1026	616	821	1095	-	958	1015	271	889	684	958	1369		711
Summit Enclosure - September 1961															
Slender wheatgrass	85	65	1368	409	701	701	1669	195	1775	65	-	130	-	Agin^2	1134
Tall oatgrass	0	0	40	25	40	40	35	0	20	0	-	40	-	Agsp	800
Mountain brome	35	40	905	990	398	398	1650	45	35	30	-	442	-	Agtr^2	110
Smooth brome	30	0	772	564	564	564	1817	50	657	40	2407	514	-	Alpr	135
Red fescue	0	0	70	55	185	185	175	0	45	0	-	15	-	Dagl	145
Native species	702	702	689	574	1001	-	328	1350	637	924	1017	320	1640		613

1/ Agin^2 = Agropyron intermedium; Agtr^2 = A. trichophorum; Agsp = Artic Agropyron; Alpr = Alopecurus pratensis, and Dagl = Dactylis glomerata.

Table 18 . Average oven dry yield in pounds per acre for planted species during the third growing season and existing native species on the check plots at Philadelphia Flat and Summit Enclosure.

Species	Fall - 1958									Spring 1959		Buffer F-1958	
	Drill spray	Drill	Contour furrows	Sawdust +N	Sawdust	Spray Drill	Summer fallow	Preparatory crop	Trans-plants	Drill	Check	Species 1/	Yield
Philadelphia Flat - September 6, 1961													
Slender wheatgrass	323	1144	1258	1201	1201	507	1431	438	-	366	-	$Agin^2$	662
Tall oatgrass	0	20	0	175	175	0	0	0	-	0	-	$Agtr^2$	137
Mountain brome	276	919	919	992	992	698	1976	1315	-		-	Agsp	229
Smooth brome	95	1684	1094	2021	2021	200	1268	170	1360	707	-	Alpr	0
Red fescue	25	0	0	70	70	0	0	10	-	0	-	Dagl	343
Native species	1160	242	677	561	-	1135	661	Not set up	677	967	967		677
Summit Enclosure - September 6, 1961													
Slender wheatgrass	165	1614	700	1454	1280	50	350	50	-	398	-	$Agin^2$	350
Tall oatgrass	0	0	0	0	0	0	0	10	-	0	-	$Agtr^2$	10
Mountain brome	20	30	40	20	0	30	20	10	-	18	-	Agsp	975
Smooth brome	20	939	427	1127	812	10	200	50	3666	826	-	Alpr	40
Red fescue	0	0	0	0	0	0	10	10	-	0	-	Dagl	0
Native species	-	579	603	715	-	392	294	718	281	660	804		482

1/ $Agin^2$ = Agropyron intermedium; $Agtr^2$ = A. trichophorum; Agsp = Artic agropyron; Alpr = Alopecurus pratensis, and Dagl = Dactylis gl rata.

Table 19 . Oven dry yield in pounds per acre for planted species during the fourth growing season and existing native species on the check plots at Philadelphia Flat and Summit Enclosure.

	Fall - 1957						Spring - 1958			Buffer F-1957	
	Drill spray	drill	Valley soil	Contour furrows	Sawdust +N	Sawdust	Drill	Trans plants	Check	Species 1/	yield
Phil. Flat - Sept. 6, 1961											
Slender wheatgrass	0	2461	1200	1520	1689	1013	169	-	-	$Agin^2$	0
Tall oatgrass	0	0	300	0	0	0	20	-	-	$Agtr^2$	0
Mountain brome	0	0	1100	2021	2325	1395	465	-	-	Alpr	0
Smooth brome	0	0	1700	0	60	0	400	3922	-	Dagl	0
Red fescue	0	0	400	0	0	0	10	-	-	Feru	0
Native species	681	576	-	749	864	-	880	884	1437		734
Summit - Sept. 6, 1961											
Slender wheatgrass	100	20	0	150	900	630	100	-	-	$Agin^2$	100
Tall oatgrass	0	0	0	0	0	0	0	-	-	$Agtr^2$	40
Mountain brome	20	0	0	0	0	0	10	-	-	Alpr	0
Smooth brome	0	0	0	0	250	175	600	140	-	Dagl	0
Red fescue	0	0	0	0	0	0	0	-	-	Feru	0
Native species	424	555	-	392	522	-	588	588	653		490

1/ $Agin^2$= Agropyron intermedium; $Agtr^2$= A. spp; Alpr = Alopecurus pratensis; Dagl = Dactylis glomerata; and Feru = Festuca rubra.

IV-D. Stand establishment and free-water in the snow and on the soil surface.

Fall plantings at high elevations in central Utah have usually been sucessful but on some local areas and in other parts of the Intermountain Region fall plantings have failed repeatedly. The reasons for these failures have been obscure since species used, seed quality, depth of planting, competition, available soil moisture, and similar factors have not appeared to be the cause of these failures. An examination of some of these plantings has shown that good stands are frequently growing on rocky ridges and south or west facing slopes when poor stands are growing on the deep fertile soils in the swales and valleys. High water marks and other signs observed in the spring of 1956 indicated that water reached a depth in excess of 3 and 5 inches, respectively, on two separate test areas. Snow survey notes substantiated these findings and indicated that melted snow water may accumulate under the snow under certain conditions.

To test this theory, free-water traps were made by placing a small can, bottom side up, over the top of an open 1/2 quart beverage can, as a loose lid. Small air holes were made on the side of this lid, allowing air to escape when water entered. These cans were fastened together with wire so that the bottom of the inverted can was at least 1/2 inch above the top of the beverage can. The larger diameter of the top can gave a minimum of 1/4 inch of space between the sides of the top can and the beverage can. These traps could only be filled by flowing water. Cans were then buried in the soil so that the lip of the beverage can was 1, 2, or 3 inches above the soil surface.

Traps set out in the fall of 1956, 1957, 1958, 1959, and 1960, and

checked in the following spring showed that free-water under snow existed on some heavy textured soil that drain rapidly when the soil is snow-free. A water table in the snow, on top of the soil is formed when the water produced on an area from rapid snowmelt plus supplemental drainage into the area exceeds the percolation rate of water into the soil plus overland drainage from this area. Overland drainage from these areas is reduced or delayed by the snowpack which not only reduces the rate of flow itself but also holds soil, litter, and sticks which also reduce the movement of water through the snow.

Row plantings were usually made adjacent to free-water traps so that correlation of seedling stands on these areas could be made with depth of free-water. Furrows 20 to 100 feet long and 4 inches deep were made with a hand cultivator. Seeds of smooth brome were planted at a depth of 3/4-inch in the bottom of each furrow with a Planet Jr. Seeding rate with the Planet Jr. was set for 10 pounds per acre when rows were spaced 1 foot apart.

Plantings were made in the fall of 1956, 1957, 1958, 1959, and 1960 on the same areas. Seedling stands in the spring of 1957, 1958, 1959, and 1960 were included in the respective reports. Seedling stands in the spring of 1960 and supplemental information are shown below.

1. Philadelphia Flat --- Elevation 10,000 feet

   a. Uniform area. Cans at 1 inch level filled. Fair to good stands of smooth brome (2.6 plants per foot).

   b. Sack and row area. Cans at 1 inch level were filled with water. Fair to good stands of smooth brome (2.2 plants per foot).

   c. From terrace up a slope. Cans at 1 inch level filled only on level terrace.

2. Summit Enclosure near uniform study area --- Elevation 10,200 feet. Free-water traps at 1 inch level were not filled with water. Only moderate flooding observed during rapid spring snowmelt. Fair to good seedling stand of smooth brome (2.5 plants per foot of row).

3. Alpine Summit. Elevation 10,200 feet. Snow cover on this west facing area was shallow in comparison to Philadelphia Flat and other level areas. Soil was frozen during most of the winter. Seeds germinated in the spring. Good seedling stands on June 22, 1961 with 4.0 seedlings per foot of row. Frost action and heaving killed some seedlings. Water traps were not filled.

4. Rock Monument on Skyline Drive. Elevation 10,300 feet. Freewater traps at 1 inch level were filled with water. Fair seedling stands of smooth brome with 2.4 plants per foot of row.

5. Bear Creek. Elevation 9,900 feet. Established on upper portion of a livestock exclosure. Good seedling stands with 9.5 plants of smooth brome per foot of row. Water traps were not filled on this area.

6. Manti Seeding. Elevation 9,800 feet.

   a. Level terrace - 5.2 seedlings per foot of row. Traps at 1 inch level filled with water.

   b. North slope - 4.3 seedlings per foot of row. No water traps filled.

   c. West slope - 4.7 seedlings per foot of row. No water traps filled.

Degree of flooding and depth of flooding during the snowmelt period in the spring of 1961 was less than in any year since observations were first made in the spring of 1956. Although frozen soil was general during the fall and early winter most of the soil had thawed prior to the rapid snowmelt period. In addition, snow accumulation during the winter period was relatively low and snowmelt was extended over a longer period of time due to cloudy skies and cold temperatures.

IV-E. Revegetation trials on range watersheds at high elevations.

Most of the intermediate and high elevation ranges are important to the Intermountain Region both as a water shed and for forage production (figures 16 and 17). Many of these ranges are in a depleted condition. Stock exclosures established on representive areas 20 to 50 years ago have shown little or no improvement through natural revegetation.

Much of the topsoil on heavily grazed ranges at high elevations has been lost by erosion. The low fertility and reduced moisture holding capacity of the soil in the remaining subsoil may be a factor in plant establishment, production of forage, and erosion control. On the subalpine plots at Bear Creek good seedling stands were obtained but plant establishment was slow. Some stands obtained have not provided the soil protection required to arrest or retard soil erosion. Where the plant cover protected the soil from active erosion relatively rapid soil build-up occurred by soil deposition from surrounding areas and accumulation of organic matter.

Soil and snow temperatures at or near the soil surface under a snow cover of one or more feet are usually around 30 to 34° F. Seed development and other physiological changes at these temperatures may determine the seedling stands produced. Freezing and thawing of the soil due to diurnal fluctuations in temperature may produce frost damage and heaving. Other factors which may influence production of seedling stands are competition for moisture, shade, moisture holding capacity of the soil, soil structure, micro-organisms in the soil, insects, rodents, and climatic conditions.

Figures 16 and 17. Most of the intermediate and high elevation ranges are important as summer range for livestock and as a watershed (61-97 and 61-126).

Annuals and ephemeralds have usually increased when the better forage plants have been weakened or killed. Control or eradication of these plants has usually been difficult and many attempts to seed areas invaded by these plants have failed. As shown in figures 18 and 19, springbeauties, larkspur, violets and similar ephemerald species grow rapidly, flower, mature seed, and largely disappear by midsummer. Forage production by these plants is usually low and herbage remaining in the late summer and fall may not be adequate to protect the soil. Some annuals such as Collomia also frequently produce seed by midsummer. Other annuals such as the tarweed shown in figure 20 usually germinate and begin to grow before the snow melts in the spring but continue to grow as long as moisture is available.

Generally speaking, good grass stands have been obtained by selected species planted by recommended methods at intermediate and high elevations (figure 21). Reduction of competing vegetation has been necessary for rapid plant establishment. Drilling with a standard drill, broadcasting and harrowing, or broadcasting on freshly plowed ground has usually given good results. But planting in furrows (deep or semi-deep) has usually given the best results.

At high elevations smooth brome has been the best single species (figure 22). Good stands have also been produced with many other species including tall oatgrass, slender wheatgrass, mountain brome, timothy, orchardgrass, intermediate wheatgrass, Kentucky bluegrass, and quackgrass. The rhizomatous grasses have usually been superior to the bunchgrasses because they spread vegetatively and are long-lived. Seedings of the rhizomatous grasses Kentucky bluegrass, quackgrass, and smooth brome made in 1917 by Dr. A.W. Sampson are still

Figure 18 and 19. Springbeauties, larkspur, violets, and similar ephemerald species grow rapidly, flower, mature seed and then largely disentigrate leaving the soil exposed (61-64 and 61-140).

Figure 20. Tarweed sprayed in the early spring of 1961 with 2,4-D at a rate of 2 lbs. per acre was killed. Most of the tarweed seed on this area had germinated prior to snowmelt in the spring of 1961 (61-153).

Figure 21. Good stands of grasses have been obtained at elevations over 10,000 feet.

Figure 22. At high elevations smooth brome has been the best single species although seedling emergence from fall plantings has been law in some years and establishment is relatively slow (61-93).

present and largely controlling soil erosion although heavy grazing has been the practice. Short-lived plants such as slender wheatgrass and mountain brome have produced good stands but these stands usually deteriorate and perish. Unless these short-lived plants are replaced through natural revegetation the soil is left bare.

Studies have shown that selected species will do well on some dry, badly eroded steep slopes once they become established. Limited plant establishment has been obtained from direct seeding on these sites, but establishment is usually slow and uncertain. Rhizome plantings have proven to be a dependable method for obtaining stands on small critical areas. Transplanting can be done in the spring, summer, or fall when the soil moisture is adequate for establishment. Spring and summer plantings have been superior to late fall planting on areas where severe frost heaving has occurred in the late fall and early spring. While vegetative propagation will have limited application it may be necessary to restore the vegetative cover on many critical areas where seed plantings have been unsucessful.